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The effects of intertidal oyster (*Crassostrea gigas*) culture on the spatial distribution of waterbirds.

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The effects of intertidal oyster culture on the spatial distribution of waterbirds

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Executive Summary

Atkins was commissioned by the Marine Institute to provide ornithological services in relation to the appropriate assessment of aquaculture and fisheries activities on coastal Special Protection Areas for birds (SPAs).

Intertidal culture of the Pacific Oyster using oyster trestles is widespread in Ireland and occurs in 16 SPAs and the potential impact of this activity on waterbird populations will be an issue in a number of Appropriate Assessments. There is little published information available about this potential impact. Therefore, a research programme was designed by Atkins, in consultation with the Marine Institute, to fill this information gap. This research programme included a review of the distribution of intertidal oyster culture in Ireland in relation to coastal Special Protection Areas, and other areas of importance for waterbirds and extensive and intensive studies of the relationship between waterbird distribution and intertidal oyster culture

Intertidal oyster culture in Ireland

Culture of the Pacific Oyster (*Crassostrea gigas*) is one of the most widespread aquaculture activities in Ireland. There are 398 active licensed plots for the culture of Pacific Oyster, although some of the plots may be designated for multiple uses. The plots occupy a total area of 4626 ha, although the actual area used for culture at any one time will be much smaller. There are also another 74 ha of applications for licenses. There are 177 active licenses for the culture of Pacific Oyster in 16 SPAs occupying a total area of 2262 ha and another 45 ha of applications for licenses.

Pacific Oyster production culture in Ireland began in the 1970s. Production levels had reached around 10,000 tonnes in 2003; they increased to around 15,000 tonnes in 2008.

Almost all Pacific Oyster culture in Ireland uses trestles in intertidal habitat. The trestles are usually located in the lower part of the intertidal zone, in areas that are only fully exposed on low spring tides. The trestles usually only occupy part of the licensed area but often also extend outside the licensed area. Large blocks of trestles are usually located on sandflats while smaller areas of trestles may occur on mixed sediment shores and muddy shores. Oyster spat is supplied by hatcheries and is placed in mesh bags. These mesh bags placed on top of the trestles, where they are on-grown until they are ready for harvesting. Oyster husbandry activities mainly take place during spring low tides. At sites with large areas of trestle blocks, husbandry activities may take place on every suitable tide.

Extensive study

The objective of this study was to identify consistent patterns across sites of positive and/or negative associations between waterbird distribution and the presence of oyster trestles.

This study was carried out in six sites: Ballymacoda Bay, Co. Cork; Bannow Bay, Co, Wexford; Castlemaine Harbour, Co. Kerry; Dungarvan Harbour, Co. Waterford; Poulnasherry Bay, Co. Clare; and Waterford Harbour, Co. Waterford. These sites were selected because: they had large areas of active trestles; suitable control habitat was available; reasonable views of the trestle areas were possible without disturbing birds; and the trestle zones supported significant numbers of waterbirds.

Between seven and fourteen count sectors were defined in each site to include the main areas of trestle activity and most, or all, areas of similar substrate type (controls). Counts were carried out on four count days at each site during spring low tide periods in January and February 2011. The timing of the counts was co-ordinated so that each site was counted during the same periods. As well as recording the numbers, location (within or outside trestle blocks), position (tideline or intertidal) and activity (feeding or roosting/other) of all waterbird species in each count sector, the position of the tideline was mapped and any potential disturbance events were recorded.

Intensive study

The objective of this study was to assess the effects of intertidal oyster farming on the detailed spatial distribution of waterbirds. This study was complementary to the strategic study: it had more statistical power and better spatial resolution, so potentially confounding effects of lateral position on the shoreline could be taken into account. However, it was limited to one site so the results were not so general.

The study area was a 2 km stretch of shore at Dungarvan Harbour, Co. Waterford. This area contained a mixture of large blocks of trestles, small blocks of trestles and clear areas. The study area was divided into seven longitudinal sectors (i.e., sectors orientated perpendicular to the shoreline) and five lateral bands (i.e., bands that are parallel to the shoreline). The study area was designed so that the tideline passed through each sector with broadly similar timing.

Counts were carried out on eight dates during January-March 2011. On each date, one or two complete counts were carried out, with a total of 13 complete counts being achieved. Numbers, activity, location (within/outside trestle areas) and position (tideline or intertidal) of birds in each band of each sector were recorded. In addition the tideline position was mapped, the percentage of each lateral band of each sector that was shallowly or deeply flooded was estimated, and oyster farming and other activities were recorded (by sector and band).

Data analysis

The tideline positions recorded on each count in both the extensive and intensive studies were digitised and used to calculate the amount of available habitat in control and impact sectors, both in terms of total intertidal habitat and length of tideline zones.

We used gradient analyses to examine the overall response of the waterbird assemblage to intertidal oyster cultivation in both the extensive and intensive studies. We carried out exploratory analyses to identify patterns of assemblage variation using Non-metric multidimensional scaling analyses (NMS). We then tested the hypothesis that waterbird assemblage variation is affected by the presence of oyster trestles, using Canonical Correspondence Analysis (CCA). For the analyses, we grouped the sectors in each site into three groups: 1. oyster trestle areas, 2. close controls and 3. distant controls. We carried out two sets of analyses: one using all species and the other using only species that predominantly feed on intertidal invertebrates.

We analysed data for individual species, in both the extensive and intensive studies, to test the null hypothesis that bird distribution within our study areas was not affected by the presence of oyster trestles, so that the observed occurrence of birds within areas of oyster trestles was not significantly different from that predicted by the percentage of the available habitat occupied by the oyster trestles. Because many waterbirds follow the tideline, and the tideline may provide particularly favourable habitat, it is necessary to consider the distribution of tideline habitat, as well as the total area of intertidal habitat in this type of analysis. Therefore, we calculated the expected number of birds in areas of oyster trestles separately for birds using tideline habitat and birds using intertidal habitat away from the tideline, and summed these two figures to provide an overall number expected within the areas of oyster trestles. For each species, we carried out two analyses: one using all the sectors and the other using the oyster trestle sectors and the control sectors close to them. We used scattergraphs to compare the data visually and to identify any differences between sites in the relationship between observed and expected numbers.

We also used data from the intensive study to compare bird densities within and outside the trestle blocks in lateral zones relative to the tideline.

Patterns of waterbird association with intertidal oyster cultivation

The non-metric multidimensional scaling analyses (NMS) and the Canonical Correspondence Analyses (CCA) produced similar arrangements of samples in the ordination space. These similarities, as well as the high eigenvalues and species-environment correlations in the CCA analyses, indicate that the SITE and OYSTER factors explained a large degree of assemblage variation. These ordinations show that the assemblage of birds occurring within an oyster trestle area is significantly different to the assemblages outside such an area at the same site.

In the species analyses most species showed similar patterns of association with oyster trestle blocks between the extensive and intensive datasets, and between the all sectors and close sectors analyses.

The species that showed a neutral/positive response are all waders that tend to feed in small flocks (Turnstone) or as widely dispersed individuals/loose flocks (Oystercatcher, Curlew, Greenshank and Redshank). The species that showed a negative response are mainly species that tend to feed in large flocks of tightly packed individuals (Knot, Sanderling, Dunlin, Black-tailed Godwit and Bar-tailed Godwit, and to a lesser extent Ringed Plover). Furthermore, for the two species out of the latter group where we had good data, the negative response appears to be stronger when large flocks are involved. The negative response to oyster trestle blocks may be a behavioural response by species where the oyster trestles interfere with their flocking behaviour by making it difficult for individuals in large flocks to remain in contact as they become dispersed across several lines of trestles.

The response of Grey Plovers in our study did not conform to the general pattern. Grey Plovers showed a strong negative response, but are a species that tends to feed as widely dispersed individuals/loose flocks. Grey Plovers have complex territorial behaviour so it is possible that the oyster trestles interfere with this territorial behaviour.

It is also notable that the species that show a negative response to oyster trestles generally favour open mudflats or sandflats and usually do not occur in large numbers in mixed sediment or rocky shores. Therefore, selection of mixed sediment or rocky shore sites for intertidal oyster culture would be likely to reduce the potential impact on waterbirds (with a few possible exceptions), and would also simply the appropriate assessment requirements.

Disturbance

Oyster husbandry activity occurred on most count days across our study sites indicating that, at least during our study period, it is likely to occur during most suitable tides. Detectable disturbance impacts to birds were only observed occasionally and were usually only minor (birds which flushed but resettled nearby). Avoidance of the vicinity of husbandry activity would have been difficult to detect in the field due to the low density and dispersed distribution of waterbirds across the sandflats at low tide. However at Dungarvan Harbour, Oystercatchers, Dunlin, Bar-tailed Godwit and Redshank were frequently observed feeding close to (within 50-100 m) husbandry activity, while gulls often followed tractors.

The effects (if any) of disturbance from husbandry activities are included in our analyses of species distribution and will, therefore, be reflected in our classification of species responses to oyster trestle blocks.

Classification of species response to intertidal oyster cultivation

Using results from both the assemblage analyses and the species analyses, we classified species' responses to intertidal oyster cultivation as follows (italics indicate that the classification is based on limited data):

- Neutral/positive response: Oystercatcher, Curlew, Redshank, Greenshank and Turnstone
- Variable response (response varies between sites): Light-bellied Brent Goose, Black-headed Gull, Common Gull and Herring Gull
- Negative response: Shelduck, Ringed Plover, Lapwing, Sanderling, Dunlin, Black-tailed Godwit, Bar-tailed Godwit, Great Black-backed Gull
- Exclusion (completely excluded from oyster trestles blocks): Grey Plover and Knot

For species that did not occur in our study sites, or for which our study did not produce sufficient data to assess their response, we have categorised their possible response based on knowledge of their behaviour and habitat preferences and, in some cases, similarity to species which we were able to evaluate:

- Possible neutral/positive response: Little Egret and Grey Heron
- Possible variable response: Lesser Black-backed Gull
- Possible negative response: Wigeon, Teal, Mallard, Pintail, Shoveler and Golden Plover

Predicting the impact of intertidal oyster culture

We have developed a methodology to provide a consistent approach to the assessment of the potential impact of intertidal oyster cultivation in the context of Appropriate Assessment of aquaculture activities in coastal SPAs.

The methodology uses the categorisation of species responses to oyster trestles derived in this study and applies to intertidal oyster cultivation in mud/sandflats. The methodology uses a displacement level of 5% as the threshold for significance: i.e., if oyster trestles are predicted to cause displacement of 5% or more of the site population of a SCI species, then the impact is considered to be significant. Where oyster trestles occur on intertidal habitat that is not exposed on every low tide, the results of assessments made using the methodology may need to be adjusted to reflect the proportion of low tides during which they are exposed.

The methodology involves the following steps: -

- Categorise the waterbird SCI species according to their potential response to intertidal oyster cultivation.
- Species with a neutral/positive response can be excluded from further assessment.
- For the other species, their spatial distribution within the site should be assessed to determine whether the intertidal oyster cultivation area(s) are within the area(s) they occupy. If the intertidal oyster cultivation area(s) are clearly outside the area(s) occupied , or which have the potential to be occupied, by the species, then the species can be excluded from further assessment.
- For the remaining species, the percentage of the site population using the intertidal oyster cultivation area(s) should be calculated, and

- For species with an **Exclusion** response, a significant negative impact is predicted where the intertidal oyster cultivation area supports, or is predicted to support in the absence of cultivation, 5% or more of the site population.

- For species with a **Negative** response, species-specific criteria, as provided in this report, should be used.

- For species with a **Variable** response, further site-specific assessment will have to be carried out.

The detailed description of the methodology in this report includes criteria for assessing the confidence levels that can be assigned to the predictions for each species, based on the level of evidence that we have to support our assessment of the species' response to intertidal oyster cultivation.

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Waterbird counts for the extensive study were carried out by Chris Cullen and Dave Daly, Michael O'Clery, Laura McNaghten, Chris Peppiatt, Pat Smiddy, Chris Wilson as part of work contracted to Birdwatch Ireland under the 2010/11 NPWS Baseline Waterbird Survey Programme. Sineád Cummins helped in organising the scheduling of the counts and the mobilisation of the counters. Additional assistance in the field was provided by Ross Macklin and Katie O'Hora, Atkins. Katie O'Hora also assisted throughout with data management and project management.

We are also grateful to Damien Predriel (Baile Mhic Coda Shellfish), Brendan Garvey, Michael Galvin, Bernard Mahony and Hugh Sheehy and various other oyster farmers that we met during fieldwork, for their co-operation with this study.

1. Introduction

1.1 Atkins was commissioned by the Marine Institute to provide ornithological services in relation to the appropriate assessment of aquaculture and fisheries activities on coastal Special Protection Areas (SPAs).

1.2 Intertidal culture of the Pacific Oyster (*Crassostrea gigas*) using oyster trestles is widespread in Ireland and occurs in 16 SPAs and the potential impact of this activity on waterbird populations will be an issue in a number of Appropriate Assessments. There is little published information available about this potential impact (see Section 3). Therefore, a research programme was designed by Atkins, in consultation with the Marine Institute, to fill this information gap.

1.3 Research was carried out in the winter of 2010/11 and consisted of three elements:

- A review of the distribution of intertidal oyster culture in Ireland in relation to coastal Special Protection Areas, and other areas of importance for waterbirds.
- An extensive study to identify consistent patterns across six sites of positive and/or negative associations between waterbird distribution and the presence of oyster trestles.
- An intensive study of the relationship to assess the effects of intertidal oyster farming on the detailed spatial distribution of waterbirds in one site with a high level of intertidal oyster culture.

1.4 This report presents a brief overview of the status and nature of intertidal oyster culture in Ireland (Section 2), reviews the scientific literature on the interactions between waterbirds and intertidal oyster culture (Section 3). We then describe the methods and present the results of the extensive and intensive studies (Sections 4-7). We have used the conclusions from our analyses of these results to categorise waterbird species in relation to their response to intertidal oyster culture (Section 8) and to develop a methodology for the assessment of the potential impact of intertidal oyster cultivation in the context of Appropriate Assessment of aquaculture activities in coastal SPAs (Section 9).

1.5 The extensive and intensive studies were designed by Tom Gittings and Paul O'Donoghue with assistance from Katie O'Hora. The counts for the extensive study were carried out by BirdWatch Ireland counters under the supervision of Atkins personnel, apart from the counts in part of one site, which were carried out by Tom Gittings. The counts for the intensive studies were carried out by Tom Gittings.

1.6 The data analysis and report writing was done by Tom Gittings; Paul O'Donoghue assisted with project design, document preparation and undertook document review. Data entry was carried out by Katie O'Hora. Tom Gittings, Ross Macklin and Katie O'Hora mapped the distribution of oyster trestles, apart from at Casltemaine Harbour.

1.7 Scientific names and British Trust for Ornithology (BTO) species codes of bird species mentioned in the text are listed in Appendix A. The BTO species codes are also used in some of the figures included in this report.

2. Intertidal oyster culture in Ireland

2.1 Culture of the Pacific Oyster (*Crassostrea gigas*) is one of the most widespread aquaculture activities in Ireland. There is also a small amount of production of the Native Oyster (*Ostrea edulis*). However, native oyster occurs as wild stocks (beds) and is not the subject of aquaculture per se, and is not considered further in this report.

2.2 There are 398 active licensed plots for the culture of Pacific Oyster, although some of the plots may be designated for multiple uses (e.g., oysters and mussels, or oysters and clams). The plots occupy a total area of 4626 ha[1] (Table 2.1), although the actual area used for culture at any one time will be much smaller (see below). There are also another 74 ha of applications for licenses.

2.3 There are 177 active licenses for the culture of Pacific Oyster in 16 SPAs: Ballymacoda Bay, Bannow Bay, Blacksod/Broadhaven Bay, Carlingford Lough, Castlemaine Harbour, Cork Harbour, Donegal Bay, Drumcliff Bay, Dundalk Bay, Dungarvan Harbour, Galway Bay Complex, Lough Swilly, Killala Bay/Moy Estuary, Shannon and Fergus Estuary, Slyne Head Islands and Trawbreaga Bay. These occupy a total area of 2262 ha (Table 2.1). There are also another 45 ha of applications for licenses.

2.4 Pacific Oyster production culture in Ireland began in the 1970s. Production levels had reached around 10,000 tonnes in 2003; they increased to around 15,000 tonnes in 2008 (Browne *et al.*, 2008).

2.5 Almost all Pacific Oyster culture in Ireland uses trestles in intertidal habitat. There is also some subtidal bottom culture in Clarinbridge, Co. Galway (Heffernan, 1999) and in Clew Bay, Co. Mayo.

2.6 Oyster trestles are usually located in the lower part of the intertidal zone, in areas that are only fully exposed on low spring tides. However, this varies between sites with Ballymacoda Bay being an example of trestles that are located at a very low elevation and Bannow Bay an example of trestles that are located at a relatively high elevation.

2.7 The trestles usually only occupy part of the licensed area but often also extend outside the licensed area.

2.8 Large blocks of trestles are usually located on sandflats while smaller areas of trestles may occur on mixed sediment shores and muddy shores.

2.9 The oyster trestles vary in height but are typically do not exceed 0.5 m height and their height above the sediment is often less as they sink into the sediment. At some sites taller trestles are present (e.g., at Ballymacoda Bay and in parts of Dungarvan Harbour).

2.10 The trestles are usually arranged in single or paired rows with a separation of around 4 m between rows and with wider (10-20 m) access lanes (Plates 1 and 2). Where the trestles occur on open sandflats the rows are usually orientated more or less perpendicularly to the tideline. At sites like Bannow Bay and Poulnasherry Bay, where the trestles occur in enclosed estuaries, the arrangement and orientation of the trestles is more variable (Plate 3).

2.11 Oyster spat is supplied by hatcheries and is placed in mesh bags. These mesh bags placed on top of the trestles, where they are on-grown until they are ready for harvesting (Plate 4). The function of the trestles is to keep the animals off the seabed, preventing grit getting inside the

[1] Note some licenses may overlap, so figures for licenses areas may be overestimates.

oysters, providing increased water flow and allowing suitable shell growth. The mesh bags facilitate handling and prevent predation (Heffernan, 1999).

2.12 Oyster husbandry activities mainly take place during spring low tides. At sites with large areas of trestle blocks, husbandry activities may take place on every suitable tide. Workers usually access the trestles by driving tractors across the beach and will often drive through shallow water on the receding tide to make the most use of the time available (Plate 5). Typically a group of around 5-10 workers would work along one-three adjacent rows of trestles (Plate 6). Husbandry activities involve turning the mesh bags every spring tide to rid the bags of any settled silt, stop the growth of oyster shell into the mesh and destroy fouling organisms (Heffernan, 1999). The level of husbandry activity appears to vary between sites and between plots within the site, with some areas having very “clean” bags and other areas having bags covered with seaweed.

2.13 At all sites, only a proportion of the trestles hold oyster bags at any one time. During our study period, trestles were moved in some sites, and the occupancy (placement of bags on the trestles) of different parts of individual trestle blocks frequently changed between consecutive counts.

2.14 Some species of birds frequently stand on top of the trestles and feed on the trestles. However, oyster farmers who we spoke to at a number of sites did not report any problems with birds predating oysters.

Table 2.1 – Numbers and areas of licenses for culture of Pacific Oysters (*Crassostrea gigas*)

Status	All licenses		Licenses in SPAs	
	Number	Area (ha)	Number	Area (ha)
Active	398	4626	177	2262
Application	88	784	45	499
Cancelled	7	16	8	35
Expired in use	2	4	20	40
Expired	26	87	22	100
Notice	39	103	2	2
Reassigned	1	4	1	2
Renewal	76	307	177	2262
Revised	10	32	45	499
Unknown	3	14	8	35
Withdrawn	5	224	20	40

Note: License data derived from shapefile supplied by the Marine Institute, September 2010.

Figures for licenses in SPAs include licenses that overlap the boundaries of SPAs.

Plate 1. Oyster trestles at Dungarvan Harbour showing typical arrangement of single and paired rows and variation between clean bags and bags with covering of algae.

Plate 2. Access lane in the main oyster trestle block at Dungarvan Harbour.

Plate 3. Irregular arrangement of oyster trestle blocks at Poulnasherry Bay.

Plate 4. Oyster bag on a trestle at Ballymacoda Bay.

Plate 5. Tractor carrying oyster farm workers accessing the oyster trestles through the receding tide at Ballymacoda Bay.

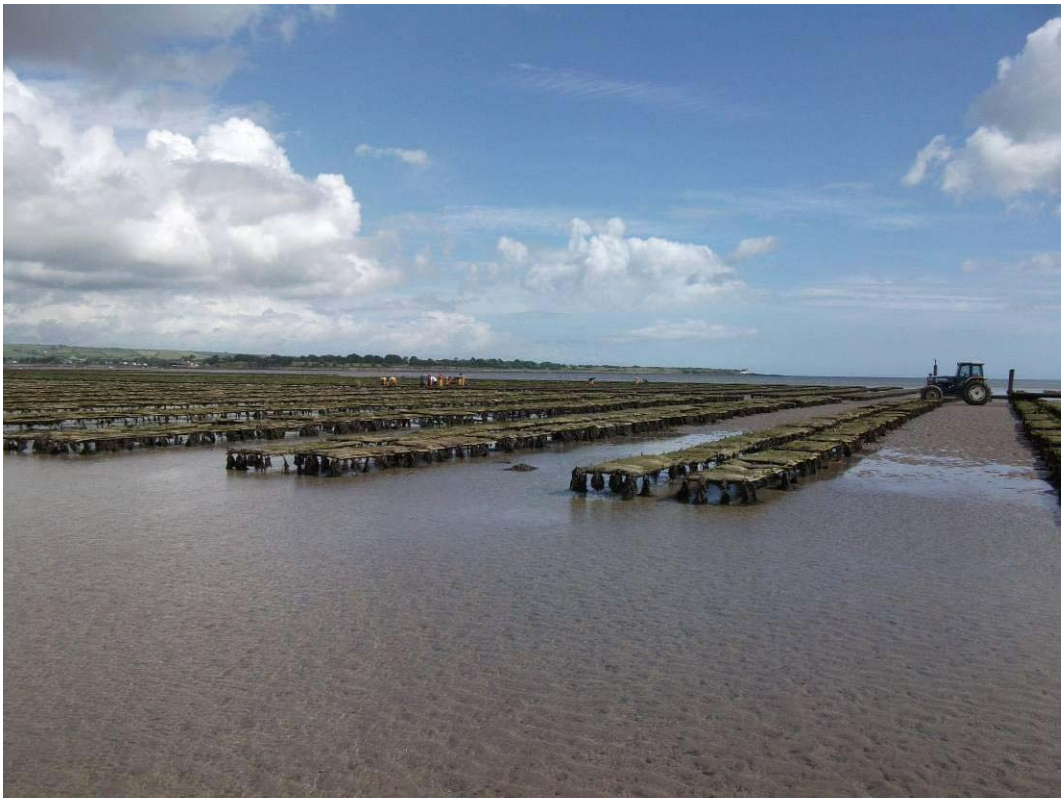

Plate 6. Oyster husbandry activity at Dungarvan Harbour.

3. Literature review

3.1 There is little published information available on the effects of intertidal aquaculture on waterbird populations in Ireland. Hilgerloh *et al*. (2001) undertook a preliminary investigation of the effect of oyster trestles on intertidal birds at a site in Cork Harbour, while Roycroft *et al*. (2004) examined the impact of suspension culture of mussels on birds and seals in Bantry Bay, in the southwest of Ireland.

3.2 This trend is repeated aboard with few detailed studies of effects of intertidal aquaculture on waterbird populations having being published in the peer reviewed literature. A number of significant exceptions include studies of intertidal mussel cultivation (Caldow *et al*., 2003), oyster trestles (Kelly *et al*., 1996; Hilgerloh *et al*., 2001), longline oyster culture (Connolly and Colwell, 2005) and intertidal clam cultivation (Godet *et al*., 2009).

Kelly *et al.* (1996)

3.3 Kelly *et al.* (1996) studied the distribution of waders in relation to intertidal oyster culture at Tomales Bay, California. They used two plots with oyster trestles and four control plots located on consolidated fine sands, silts, and clays. Each plot occupied 225 m of shoreline and around 2 ha of intertidal habitat. They carried out three counts per month across five winters (November-February).

3.4 They found that then abundances of Western Sandpiper and Dunlin were significantly lower in the aquaculture plots, while the abundance of Willet was significantly higher. There were no significant difference between aquaculture and control plots in the abundances of Grey Plover[2], Marbled Godwit, Sanderling and Least Sandpiper.

3.5 Oyster workers were present in the aquaculture plots on 62% of the counts but were not observed to cause movements of birds into or out of the plots. The distributions of shorebirds were not significantly related to the presence of the oyster workers.

3.6 The study design partly confounded treatment effects with spatial variation because the two aquaculture plots were next to each other. While various analyses indicated that there was not any underlying habitat gradient, the authors acknowledge that their study did not rule out the possibility “that observed differences between control and aquaculture areas resulted from underlying (pre-aquaculture) habitat conditions along a larger habitat gradient”.

3.7 Therefore, while this study provides some interesting results, the low number of replicates and the possibly confounding effects of spatial variation mean that its results should be treated with caution.

Hilgerloh *et al.* (2001)

3.8 Hilgerloh *et al.* (2001) studied the distribution and behaviour of waterbirds in relation to intertidal oyster culture at Cork Harbour. They used one plot with oyster trestles and one control plot (both 1 ha) located on mudflats in Saleen Creek on the eastern side of Cork Harbour. They carried out 64 scan counts and a series of focal observations on four days between 2nd and 7th March 1999.

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[2] Referred to as Black-bellied Plover in Kelly *et al.* (2006).

3.9 Oystercatcher, Curlew, Black-headed Gull and Common Gull occurred in significantly lower numbers[3] in the trestle area compared to control plot, while there was no difference in the numbers of Dunlin and Redshank. There was no significant difference in the percentage of feeding birds of any of these species between the plots and the feeding rate of Oystercatchers did not differ between the plots. They also report various data on the behaviour of birds in areas of trestles with bags compared to areas without bags.

3.10 This study has no replication of treatments and the authors acknowledge that “the differences observed in the distribution of the other species [Oystercatcher, Curlew, Black-headed Gull and Common Gull] cannot only be explained by the presence of the trestles, since not all environmental parameters were identical in both areas”. Furthermore, the very limited temporal range of the study (five days between the first and last count days) means that the results may not be very representative of overall distribution patterns.

Connolly and Colwell (2005)

3.11 Connolly and Colwell (2005) studied the distribution, abundance and diversity of waterbirds in relation to intertidal longline oyster culture at Humboldt Bay, California.

3.12 The longline oyster culture involved lines of oysters suspended from plastic pipes inserted vertically into the substrate. The lines were usually spaced into rows 70 cm wide, and the photograph in Figure 2 of Connolly and Colwell (2005) indicates that the height of the lines above the substrate was similar to this width. At three sites, every fifth row was 1.5 m wide, and at all sites there were regular 2 m wide aisles perpendicular to the rows.

3.13 They used five study sites, with a longline plot paired with a control plot that was similar in area, shape, substrate, micro-channelization and elevation. They carried out bird counts on 129 days between 1st June 1999 and 31st May 2000. They also recorded the following habitat parameters in each of the longline and control plots: percentage cover of oyster shell and eelgrass, penetrability of the sediment, and core samples of subsurface debris.

3.14 The longline plots were similar in habitat to each other while the control plots had lower shell cover, lower shell mass, higher eelgrass cover and lower penetrability than the longline plots.

3.15 They compared waterbird abundances on longline and control plots separately for each study site. In 32 of the 68 pairwise comparisons, there were significant differences between longline and control plots, with higher numbers in the longline plots in 25 of these comparisons. Species that were more abundant in longline plots (number of sites in parentheses) were: Great Egret [Great White Egret] (1), Snowy Egret (3), Black-crowned Night-heron [Night Heron] (2), Peeps (2), Dowitcher (1), Whimbrel (4), Willet (4), Black Turnstone (2). Species that were more abundant in control plots (number of sites in parentheses) were: Great Blue Heron (1) and Grey Plover[4] (2). Species with mixed responses were: Dunlin (more abundant on longline plots in 1 site, more abundant on control plots in 2 sites), Marbled Godwit (3, 1) and Long-billed Curlew (1, 1). Species diversity was greater on longline plots compared to control plots. In 15 of 60 comparisons, bird use of wide areas exceeded availability, with the strongest preference for wide rows being among the larger species.

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[3] The authors present data on densities in the tables in the paper but refer to numbers in the text.
[4] Referred to as Black-bellied Plover in Connoly and Colwell (2005).

4. Methods: Extensive study

Study design

4.1 The objective of this study was to contribute to an assessment of whether the spatial distribution of waterbirds is affected by the presence of oyster trestles. In particular, this study aimed to identify whether there were consistent patterns of positive or negative association with oyster trestles across a range of sites. The study examined the distribution of waterbirds in six sites. In each site waterbirds were counted in sectors defined by the presence of oyster trestles (Impact) and the occurrence of similar areas of substrate without oyster trestles (Control).

Site selection

4.2 We selected sites using the following criteria:

- Large area of active trestles occupying a wide longitudinal zone on the shoreline;
- Availability of suitable control habitat;
- Vantage points for counting that can be safely accessed early on the falling tide without disturbing birds in the trestle zone and that provide views between the rows of trestles; and.
- Support significant numbers of waterbirds within the part of the site used for trestles.

4.3 We reviewed a GIS layer of oyster licenses and identified sites that appeared to be potentially suitable. We then consulted with local BIM staff to confirm the extent, current activity and accessibility of the oyster trestles on the sites. Several potential sites were ruled out at this stage. We then visited the following sites during spring low tides in September and October 2010: Ballylongford (Shannon), Ballymacoda, Bandon Estuary and Oysterhaven, Bannow Bay, Castlemaine Harbour, Cork Harbour, Donegal Bay, Dungarvan, Poulnasherry (Shannon) and Waterford Harbour.

4.4 We selected the following six sites: Bannow Bay, Co, Wexford; Waterford Harbour and Dungarvan Harbour, Co. Waterford; Ballymacoda Bay, Co. Cork; Castlemaine Harbour, Co. Kerry; and Poulnasherry Bay, Co. Clare. Of these sites, Ballymacoda Bay, Dungarvan Harbour and Waterford Harbour clearly satisfied all the criteria. At the other sites, there were some issues with some of the criteria, but these sites were selected as the best available. In addition, data was required for Castlemaine Harbour to contribute towards the Appropriate Assessment that was being prepared for that site at the time.

Habitat surveys

4.5 Oyster trestles were mapped by GPS in all of the study sites. The oyster trestles in Ballymacoda Bay, Bannow Bay, Dungarvan Harbour and Poulnasherry Bay were mapped in September-November 2010, with additional mapping at Ballymacoda Bay and Dungarvan Harbour in January-March 2011. The location of the trestles at Castlemaine Harbour was mapped approximately by eye in November 2010, and mapped by GPS in February 2011. The trestles at Waterford Harbour were mapped by GPS in February 2011. All the mapping was done by Atkins personnel, except for the mapping at Castlemaine Harbour which was done by Department of Agriculture Fisheries and Food personnel.

4.6 We assessed the extent of intertidal habitat of similar substrate-type to that occupied by the oyster trestles, using biotope maps (where available) and walkover surveys.

4.7 Biotope maps were available for Bannow Bay, Castlemaine Harbour, Dungarvan Harbour and Waterford Harbour. However, some caution is necessary in the interpretation of the results of these surveys. The biotope classifications are based mainly on the results of point samples and it is often not clear how the boundaries of the biotopes have been defined. Therefore, we verified biotope boundaries, where possible, in the field, and were cautious in the interpretation of small-scale variation in biotopes. Our interpretation of the biotope maps for individual sites is discussed below in paragraphs 4.29, 4.40, 4.45, 4.51 and 4.57.

Site descriptions

Ballymacoda Bay

4.8 Ballymacoda Bay is the estuary of the Womanagh River near Youghal, Co. Cork. It is a SPA with 11 species listed as SCIs and is internationally important for Golden Plover, Black-tailed Godwit and Lesser Black-backed Gull and nationally important for another 11 species (Table 4.1).

4.9 The site is divided by sand dune spits at Ring Point with an enclosed muddy estuary to the west and open sandflats to the east.

4.10 The oyster trestles occur in a single block on the lower sandflats in the outer section of the bay, south of the Womanagh River channel (Figure 4.1). They occupy an area of around 22 ha. They are at a very low elevation and are only fully exposed on the lowest spring tides. The trestles occupy most of the licensed area, and the lowermost sections extend slightly below the licensed area.

4.11 Our study area covered 335 ha and included the entire open sandflat habitat to the east of Ring Point. It comprised around 75% of the total area of intertidal habitat in Ballymacoda Bay SPA (Figure 4.1).

Table 4.1 – Important waterbird species at Ballymacoda Bay.

Status	Species	Mean annual peak 1996-2000[1]	SCI Species
International	Golden Plover	11390	x
	Black-tailed Godwit	1044	√
	Lesser Black-backed Gull	6851	x
National	Wigeon	889	√
	Teal	935	x
	Ringed Plover	158	√
	Grey Plover	552	√
	Lapwing	4053	√
	Knot	330	x
	Sanderling	97	√
	Dunlin	3333	x
	Bar-tailed Godwit	622	√
	Curlew	1172	√
	Redshank	358	√
Gulls	Black-headed gull	3633	x
	Common gull	2633	√
	Lesser Black-backed gull	6851	x
Additional SCI species	Turnstone		√

[1] Source: Crowe (2005)

Bannow Bay

4.12 Bannow Bay is the estuary of the Corock and Owenduff Rivers, near Fethard, Co. Wexford. It is a SPA with 13 species listed as SCIs and is internationally important for Light-bellied Brent Goose and Black-tailed Godwit and nationally important for another 11 species (Table 4.2).

4.13 The site is an enclosed estuary with a mixture of *coarse sands at the mouth of Bannow Bay, sands and muddy sands within the outer areas of Bannow Bay, macrophyte dominated sediment in sheltered backwaters and mixed muddy gravels and muds in the sheltered upper and mid estuarine areas of the bay* (Aquatic Services Unit, 2010).

4.14 Oyster trestles occur in the middle section of the estuary just to the north of Saintkierans (Figure 4.2). There are around 19 ha of oyster trestles, in several blocks, on open mudflat/sandflat habitat in the middle part of the channel. These trestles are almost entirely within areas that are either licensed or have license applications. There is an additional licensed area of around 19.5 ha, and additional license applications of around 12.5 ha that are unoccupied in this zone. There are also additional smaller areas of oyster trestles on mixed sediment habitat along the western and eastern sides of the estuary.

4.15 Our study area covered 275 ha and included most of the upper section of the estuary above Saintkierans (Figure 4.2). It comprised 29% of the 937 ha of intertidal habitat mapped by Aquatic Services Unit (2010) in Bannow Bay.

Table 4.2 – Important waterbird species at Bannow Bay.

Status	Species	Mean annual peak 1996-2000[1]	SCI Species
International	Light-bellied Brent Goose	471	√
	Black-tailed Godwit	648	√
National	Shelduck	502	√
	Pintail	38	√
	Oystercatcher	791	√
	Golden Plover	2256	√
	Grey Plover	90	√
	Lapwing	3274	√
	Knot	464	√
	Dunlin	2798	√
	Bar-tailed Godwit	446	√
	Curlew	908	√
	Redshank	350	√

[1] Source: Crowe (2005)

Castlemaine Harbour

4.16 Castlemaine Harbour is an intertidal complex around the estuary of the Maine and Laune Rivers near Killorglin, Co. Kerry. It is a SPA with 16 species listed as SCIs and is internationally important for Light-bellied Brent Goose and nationally important for another 15 species (Table 4.3).

4.17 Most of the intertidal habitat is in a wide bay that is sheltered by the Cromane peninsula and the Inch sand dunes. This area is mainly occupied by extensive sandflats of fine to muddy fine sand with polychaetes, with muddier biotopes in the upper shore zones (National Parks and Wildlife Service, 2011).

4.18 Oyster cultivation occurs along the southern side of Castlemaine Harbour, between Cromane Point and Douglas Strand (Figure 4.3). Cultivation began in 1993. Production levels were 145 tonnes in 2008 and 97 tonnes in 2009. There are a total of 34 separate blocks of trestles, occupying an area of 5.4 ha. The largest block covers an area of 1.1 ha and most blocks (21 of the 34 blocks) are less than 0.1 ha in size. The trestle blocks only occupy a small proportion of the licensed area, although some blocks occur outside licensed plots, and around 48 ha of the licensed area is currently unoccupied.

4.19 Our study area covered 1391 ha along the southern side of Castlemaine Harbour, between Cromane Point and Douglas Strand (Figure 4.3). The study area comprised 32% of the 4287 ha of the mudflats and sandflats not covered by seawater at low tide habitat mapped by National Parks and Wildlife Service (2011) in Castlemaine Harbour and a large proportion of the total intertidal area of the intertidal fine to muddy fine sand with polychaetes community complex.

Table 4.3 – Important waterbird species at Castlemaine Harbour.

Status	Species	Mean annual peak 1996-2000[1]	SCI Species
International	Light-bellied Brent Goose	539	√
National	Red throated diver	19	√
	Great northern Diver	20	x
	Cormorant	118	√
	Wigeon	6811	√
	Pintail	117	√
	Scaup	79	√
	Common scoter	2423	√
	Oystercatcher	895	√
	Ringed Plover	214	√
	Grey Plover	45	x
	Sanderling	349	√
	Bar-tailed Godwit	398	√
	Redshank	344	√
	Greenshank	43	√
	Turnstone	110	√
Additional SCI species	Mallard		√
	Chough		√

[1] Source: Crowe (2005)

Dungarvan Harbour

4.20 Dungarvan Harbour is large bay around the estuaries of the Colligan and Glendine Rivers and the River Brickey. It is adjacent to the town of Dungarvan in Co. Waterford. It is a SPA with 15 species listed as SCIs and is internationally important for Light-bellied Brent Goose and Black-tailed Godwit and nationally important for another 12 species (Table 4.4).

4.21 The site is divided by a sand dune spit at the Cunnigar with sheltered intertidal mud and muddy sands to the west and open sandflats to the east. According to Aquatic Services Unit (2009), the latter are dominated by the *Polychaetes and Angulus tenuis in littoral fine sand* biotope. They also map small areas of the *Lanice conchilega in littoral sand* biotope on both the north and south sides of the bay. However, they only took one sample in lower shore zone on the southern side of the bay and our own observations indicate that *Lanice conchilega* is abundant across much of the lower shore zone on this side of the bay. An area of mixed sediment shore extends out across the sandflats on the northern side of the bay.

4.22 The site has the largest area of oyster cultivation in Ireland. The oyster trestles are on the lower sandflats on the southern side of the bay, extending along almost the full length of the shoreline (Figure 4.4). There is one large block and several smaller blocks occupying an area of around 100 ha. The trestles extend across most of the licensed area. Significant areas of trestles occur in the upper shore zone outside the licensed area, while the licensed blocks in the lower shore zone were unoccupied.

4.23 Our study area covered 807 ha and included most of the outer part of the bay, east of the Cunnigar and north and south of the main tidal channel (Figure 4.4). The study area comprised 38% of the 2101 ha of intertidal habitat mapped in Dungarvan Harbour by Aquatic Services Unit (2009) and all of the area occupied by the *Polychaetes and Angulus tenuis in littoral fine sand* biotope.

Table 4.4 – Important waterbird species at Dungarvan Harbour.

Status	Species	Mean annual peak 1996-2000[1]	SCI Species
International	Light-bellied Brent Goose	521	√
	Black-tailed Godwit	736	√
National	Shelduck	497	√
	Red-breasted Merganser	54	√
	Oystercatcher	784	√
	Golden Plover	4700	√
	Grey Plover	433	√
	Lapwing	3097	√
	Knot	624	√
	Dunlin	4567	√
	Bar-tailed Godwit	936	√
	Curlew	841	√
	Redshank	687	√
	Turnstone	169	√
Gulls	Lesser Black-backed Gull	1343	x
Additional SCI species	Great Crested Grebe		√

[1] Source: Crowe (2005)

Poulnasherry Bay

4.24 Poulnasherry Bay is a small bay on the northern side of the Shannon Estuary near Kilrush, Co. Clare. It is part of the Shannon & Fergus Estuary SPA. This SPA has 22 species listed as SCIs and is internationally important for -bellied Brent Goose, Black-tailed Godwit and Redshank and nationally important for another 2 species (Table 4.5).

4.25 The site is an enclosed estuary with intertidal mud and sandflats and extensive areas of mixed sediment shore.

4.26 One large (9 ha) block of trestles occurs on muddy sand substrate on the western side of the estuary south of Black Island (Figure 4.5). These trestles are almost entirely within the licensed area, and there is an additional licensed area of around 12 ha that is unoccupied in this zone. Several other smaller blocks of oyster trestles occur along both sides of the main tidal channel around Black island and Illaunallea on mixed sediment substrate, and at the mouth of the bay at Cammogue Point and Baurnahard Point.

4.27 Our study area covered 55 ha and included discrete areas of muddy sand habitat in various locations along the main tidal channel (Figure 4.5). The study area comprised around 20% of the total area of intertidal habitat in Poulnasherry Bay and all of the area occupied by muddy sand habitat of similar consistency to that within the main oyster trestle block.

Table 4.5 – Important waterbird species in the Shannon and Fergus Estuary.

Status	Species	Mean annual peak 1996-2000[1]	SCI Species
International	Light-bellied Brent Goose	509	√
	Black-tailed Godwit	2024	√
	Redshank	2289	√
National	Cormorant	357	√
	Whooper Swan	153	√
	Shelduck	1243	√
	Wigeon	5799	√
	Gadwall	32	
	Teal	2610	√
	Pintail	69	√
	Shoveler	107	√
	Scaup	129	√
	Moorhen	41	x
	Ringed Plover	145	√
	Golden Plover	6684	√
	Grey Plover	419	√
	Lapwing	7166	√
	Knot	2001	√
	Dunlin	3174	√
	Bar-tailed Godwit	608	√

Status	Species	Mean annual peak 1996-2000[1]	SCI Species
	Curlew	2550	√
	Greenshank	71	√
Gulls	Black-headed Gull	2827	√
	Common Gull	470	x

[1] Source: Crowe (2005)

Waterford Harbour

4.28 Waterford Harbour is the lower part of the estuary of the Rivers Barrow and Suir. It is not part of any SPA but is a SAC and pNHA. It is nationally important for Oystercatcher and Bar-tailed Godwit (Table 4.6).

4.29 It is dominated by a wide and deep tidal channel with only limited areas of intertidal habitat. The main area of intertidal habitat occurs on the western side of the harbour where sandflats extend from Passage East south to Creadan Head. The lower shore zones in this area are dominated by fine sand with polychaetes biotopes, with the *Cerastoderma edule and polychaetes in littoral muddy sand* in the upper shore zones of Dromina and Woodstown Strands (Aquatic Services Unit, 2008b). The abundance of *Cerastoderma* however is highly variable at this site annually (Marine Institute surveys 2007-2011). Mixed sediment shore occupies the upper shore zone of Passage Strand[5].

4.30 Oyster trestles occur along the lower shore in the southern part of these sandflats (Figure 4.6). There are semi-continuous blocks extending along 2.5 km of the shore and occupying a total area of 42 ha. The southern half of the oyster trestle blocks are largely upshore of the licensed area, and there are extensive unoccupied licensed areas downshore of the trestles and in Fornaght Strand.

4.31 Our study area covered 385 ha and included the entire lower shore fine sand habitat between Passage East and Creadan Head, as well as an isolated area of lower shore fine sand habitat on the eastern side at Duncannon (Figure 4.6). The study area comprised 51% of the 749 ha of intertidal habitat in Waterford Harbour mapped by (Aquatic Services Unit, 2008b).

Table 4.6 – Important waterbird species at Waterford Harbour.

Status	Species	Mean annual peak 1996-2000[1]
National	Oystercatcher	784
	Bar-tailed Godwit	166

[1] Source: Crowe (2005).

[5] This area is incorrectly mapped as *Cerastoderma edule and polychaetes in littoral muddy sand* by Aquatic Services Unit (2008b).

Count sectors

4.32 The general location of the count sectors, the habitat types included in the sectors and the criteria used to define the count sectors are described below. Details of the definition of the count sector boundaries are included in Appendix A.

4.33 In most cases, the position of tidal channels and the extent of intertidal sediments on the Ordnance Survey Discovery Series map are incorrect and were redrawn (based on recent aerial photographs, field observations and/or biotope maps) while defining the count sector boundaries.

Ballymacoda Bay

4.34 The count sectors used in Ballymacoda Bay are shown in Figure 4.7.

4.35 The oyster trestles occur on fine sand substrate on the southern side of Ballymacoda Bay. The count sectors used include this area of oyster trestles and other areas of similar substrate type without oyster trestles. There is no biotope map available for Ballymacoda Bay. However, our field observations indicate that similar substrate occurs throughout the southern side of Ballymacoda Bay, although possibly becoming somewhat muddier closer to the dunes.

4.36 Extensive areas of fine sand substrate also occur on the northern side of the bay in a mosaic with mixed sediment substrate. The latter comprises scattered gravel/cobbles on firm sand with patches of dense hard sediment and some mussel beds. Because of the generally diffuse nature of the transitions between the muddy sand and mixed sediment substrates in this area, it was not practicable to define easily identifiable count sector boundaries that reflect differences in substrate type. Instead, the count sector boundaries used in the NPWS low tide counts were used, and the recording methodology was designed to discriminate between birds using the different substrate types.

4.37 All the count sectors were in areas of fine sand or mixed sediment substrate. Where count sectors extended up to the shoreline any distinct shoreline zones of different substrate (e.g., a dry sand beach or rocky shore) were excluded during the counts.

4.38 In the field, the lower limit of most of the count sectors was defined by the tideline and varied between count days depending on the height of the tide.

Bannow Bay

4.39 The count sectors were defined using a biotope map of Bannow Bay (Aquatic Services Unit, 2010) and field observations and covered the main areas of oyster trestles and areas of similar substrate type without oyster trestles (Figure 4.8).

4.40 The distribution of the count sectors in relation to the mapped biotopes is shown in Figure 2. There are some discrepancies between the mapped biotopes and the count sector boundaries. The biotopes appear to have been mapped using the Ordnance Survey Discovery Series map as a base. However, the mapping of the tidal channels in the latter is incorrect and the current alignments of the tidal channels were followed in defining the count sector boundaries. Furthermore, the boundary between LS.LSa.MuSa and LS.LMu.MEst.HedMacScr in the vicinity of the oyster trestles does not correspond to the distribution of muddier and sandier sediments observed in the field. These occur in a complex mosaic in this area. In addition, count sector boundaries were defined so as to be easily recognisable in the field.

4.41 There are additional areas of oyster trestles on gravel substrates along the upper shore on both sides of the estuary. These were not included in the count sectors and are not mapped on Figure 4.2.

4.42 All the count sectors are in areas of mud or muddy sand substrate. Where count sectors extended up to the shoreline areas of rocky or gravelly substrate along the shoreline were excluded during the counts.

4.43 The OY sectors were sub-divided to allow separate counting of discrete groups of oyster trestle blocks, to allow analysis of the effect of differences in detectability on bird numbers recorded (Figure 4.9).

Castlemaine Harbour

4.44 The count sectors were defined using a biotope map of Castlemaine Harbour and field observations to cover the main areas of oyster trestles and areas of similar substrate type (Figure 4.10). Aquaculture license applications were also taken into account in defining the count sectors.

4.45 There are two different versions of the biotope map of Castlemaine Harbour (Aquatic Services Unit, 2008a; NPWS, 2011). Neither of these versions correctly map the configuration of the tidal channels and there are significant differences between the versions in terms of their classification of substrates within our study area. Based on our field observations, the 2008 ASU biotope map version was used to help define divisions between count sectors along the southern side of the study area (in order to reflect differences between sandier and muddier substrates). However, the distinctions in the ASU map between fine sand and muddy sand substrates in the outer part of our study area does not correspond to any obvious observed differences in sediment type in the field and was, therefore, not used to define sector boundaries.

4.46 There are a number of applications for aquaculture licenses in the southern part of the study area (Figure 4). Some of the count sectors were defined so that they can provide baseline data for future monitoring of the impact of aquaculture in these areas.

4.47 The count sectors included areas of fine sand, muddy sand and mixed sediment substrate. Where count sectors extended up to the shoreline any distinct shoreline zones of different substrate (e.g., a shingle beach) were excluded during the counts.

4.48 There were five count sectors containing oyster trestles. In each of these sectors, the oyster trestles only occupied small proportions of the sector.

4.49 Sector C1 was difficult to count accurately because of the size of the sector and the distance of the outer parts from the vantage point. On each count, distant flocks of up to 500 waders that could not be identified were noted. Therefore, this sector has been excluded from the main analyses.

Dungarvan Harbour

4.50 The count sectors were defined using a biotope map of Dungarvan Harbour (Aquatic Services Unit, 2009) and field observations to cover the main areas of oyster trestles and areas of similar substrate type without oyster trestles (Figure 4.11). The division of the count sectors on the north side of the bay reflects variation in width of the intertidal habitat (and potential degree of influence of tidal channels).

4.51 The distribution of the count sectors in relation to the mapped biotopes is shown in Figure 2. The count sectors covered the full extent of the LS.LSa.FiSa.Po.Aten biotope at Dungarvan Harbour.

An area of LS.LSa.MuSa.CerPo biotope was included as it is contiguous with the main area of LS.LSa.FiSa.Po.Aten biotope. Two pockets of LS.LSa.MuSa.Lan biotope have been mapped within the LS.LSa.FiSa.Po.Aten biotope. These areas are not visibly different in the field. The reliability of the mapped extent of these areas is not clear as they appear to have been mapped based on single point samples. Therefore, these biotopes were not used to define count sectors.

4.52 All the count sectors are in areas of mud or muddy sand substrate. Where count sectors extend up to the shoreline areas of rocky or gravelly substrate along the shoreline were excluded during the counts.

4.53 Sector CN5 was difficult to count accurately due to poor visibility from the western shore and distance when counting from the northern shore. Counts of small waders were considered to be unreliable, while identification of godwit species was not always possible. In addition, the sector was only briefly exposed during the counts and birds in this sector may have been double-counted on other sectors. Therefore, this sector has been excluded from the main analyses.

Poulnasherry Bay

4.54 The main area of oyster trestles occurs on muddy sand substrate south of Black Island. The count sectors included this area of oyster trestles and areas of similar substrate type without oyster trestles (Figure 4.12). The main area of oyster trestles was mapped by GPS. There is no biotope map available for Poulnasherry Bay so the control sectors were identified by field observations.

4.55 Additional, smaller, areas of oyster trestles occur along rocky/gravel substrates. These areas were not included in the count sectors.

Waterford Harbour

4.56 The count sectors were defined using a biotope map of Waterford Harbour (Aquatic Services Unit, 2008b) and field observations to cover the main areas of oyster trestles and areas of similar substrate type (Figure 4.13).

4.57 The distribution of the count sectors in relation to the mapped biotopes is shown in Figure 2. The count sectors covered all the mapped areas of fine sand biotope in Waterford Harbour. The lower limits of some of the count sectors were extended below the mapped biotopes to reflect the observed exposure of the oyster trestles in the field. However, these lower boundaries are only indicative and in the field these boundaries were defined by the tideline. There are also areas of intertidal habitat near Creadan Head that are not covered by the biotope map. The count sector boundaries in these areas were interpolated from the adjacent areas with mapped biotopes. All the count sectors were in areas of fine sand substrate. Where count sectors extended up to the shoreline areas of rocky or gravelly substrate along the shoreline were excluded.

4.58 Because of tidal restrictions and adverse weather, it was not possible to map the extent of the oyster trestles before the start of the study. On a preliminary visit, we noted that the licensed blocks appeared to at least approximately correspond to the extent of the trestles. Therefore, these blocks were used to define the oyster trestle count sectors. However, subsequent mapping in February 2011 showed that the trestle locations did not correspond exactly to the licensed areas. Therefore, the extent of sectors OY1 and OY2 was re-defined following the mapping of the trestles. This re-definition also meant that sector C3, which had been upshore of sector OY1, no longer occupied a clearly defined area and would probably fall within the muddy sand biotope. Few birds were recorded in sector C3 and we have excluded it from the analyses. In addition, only small areas of sector C2 were exposed during the counts and we have combined sectors C1 and C2 for the purposes of the data analyses.

Waterbird counts

4.59 Waterbird counts were carried out by Tom Gittings and by counters from the NPWS Baseline Waterbird Survey Programme under the supervision of Atkins (Table 4.7). Two counters were used for Ballymacoda Bay and Dungarvan Harbour, because of the logistics of the sites, while all the other sites were counted by single counters.

Table 4.7 – Counters.

Site	Sub-division	Counter
Ballymacoda Bay	Northern sectors Southern sectors	Chris Cullen Pat Smiddy
Bannow Bay		Chris Wilson
Castlemaine Harbour		Micheal O'Clery
Dungarvan Harbour	Northern sectors Southern sectors	Laura O'Mahony Tom Gittings
Poulnasherry Bay		Chris Peppiatt
Waterford Harbour		Dave Daly

4.60 Waterbird counts were carried out on four dates in January and February 2011, with an additional fifth count at Dungarvan Harbour in March 2011. A single full count was completed at each site on each count day, with the exception of Ballymacoda Bay where two full counts were completed on each count day. At Dungarvan Harbour and Poulnasherry Bay partial second counts, and at Ballymacoda Bay partial third counts, were carried out on some count days.

4.61 Counts were carried out during spring low tide conditions when the exposure of the oyster trestles was maximal. Weather conditions were generally good during the counts, although strong winds and rain affected some of the counts during the third count period, and fog affected some counts during the fourth count period (Table 4.8).

Table 4.8 – Details of the timing of the extensive study counts and low tide and weather conditions during the counts.

Count period	Site	Date	Low tide[1]		Count times		Weather			
			Time	Height	Start	Finish	Cloud cover[2]	Wind[3]	Rain[4]	Visibility[5]
1	BANN	04 Jan	11:43	0.9 m	10:43	13:18	2-3	SW1-4	1	1
	CAST	05 Jan	11:52	1.0 m	11:30	14;25	1-2	S-SW1-3	1	1
	CODA	04 Jan	11:48	0.6 m	10:21 12:33	12:35 14:15	2-3	SW-NW1-2	1	1-2[7]
	DUNG	06 Jan	13:01	0.6 m	11:10	14:40	2-3	W-N1-4	1	1
	FORD	04 Jan	11:47	0.9 m	10:20	14:25	2-3	S1-3	1	1-2[10]
	POUL	04 Jan	11:32	0.7 m	11:15	13:22	3	SW3	1	1
2	BANN	23 Jan	14:07	0.6 m	12:37	15:08	3	N2	1	1
	CAST	24 Jan	14:31	0.8 m	12:45	17:20	2-3	E1-2	1	1
	CODA	20 Jan	12:06	0.4 m	10:15 12:00	12:13 13:55	1	E-S1-2	1	1
	DUNG	22 Jan	13:30	0.4 m	11:15	14:47	1-3	W-N1-2	1	1
	FORD	19 Jan	11:22	0.8 m	09:05	13:43	1	N0-1	1	1
	POUL	21 Jan	11:13	0.6 m	11:00	14:01	1	0	1	1
3	BANN	03 Feb	12:07	0.8 m	10:37	13:11	3	SW6-8	1	1
	CAST	03 Feb	11:37	0.9 m	10:50	14:18	3	SW5-8	1-3	1-2[6]
	CODA	08 Feb	14;42	0.8 m	13:05 14:20	14:48 15:51	2-3	SSE-SSW2-4	1-3	1-3[8]
	DUNG	03 Feb	12:11	0.6 m	10:15	13:22	2-3	SE-SW4-6	1	1
	FORD	03 Feb	12:11	0.8 m	10:30	13:58	3	SW7-8	1	1-2[11]
	POUL	03 Feb	11:56	0.6 m	11:45	13:50	3	SW2-4	2	2
4	BANN	17 Feb	10:58	0.7 m	09:33	12:18	3	SE0-1	1	1
	CAST	23 Feb	14:53	0.7 m	14:10	17:45	1-3	SW4	1	1
	CODA	21 Feb	13:54	0.1 m	12:00 13:40	14:15 16:00	1-2	E0-2	1	1
	DUNG	21 Feb	13:52	0.2 m	11:46	16:08	1-3	N-SE1-3	1-3	1-2[9]
	FORD	17 Feb	11:02	0.7 m	09:30	13:52	3	NE-SE1	1	1-2[12]
	POUL	20 Feb	10:54	0.5 m	13:21	15:07	3	SW1-2	2	1-3

Count period	Site	Date	Low tide[1]		Count times		Weather			
			Time	Height	Start	Finish	Cloud cover[2]	Wind[3]	Rain[4]	Visibility[5]
5	DUNG	03 Mar	11:16	0.6 m	09:18	12:50	1	N-E1-2	1	1

[1] source: Admiralty EasyTide (http://easytide.ukho.gov.uk/) data for Cromane (Castlemaine Harbour), Dunmore East (Waterford Harbour), Fethard-on-Sea (Bannow Bay), Dungarvan (Dungarvan Harbour), Kilrush (Poulnasherry Bay) and Youghal (Ballymacoda Bay).
[2] 1 = 0-33%, 2 = 33-66%, 3 = 66-100%
[3] Beaufort scale and direction
[4] 1 = none, 2 = showers, 3 = drizzle
[5] 1 = good, 2 = moderate, 3 = poor
[6] moderate on three of the sector counts
[7] moderate on four of the sector counts in count series 1
[8] moderate on three counts and poor on three counts in count series 2
[9] moderate on two of the sector counts
[10] moderate on two of the sector counts
[11] moderate on four of the sector counts
[12] moderate on two of the sector counts

4.62 Counts in the oyster trestle sectors (and adjacent control sectors) at Ballymacoda Bay, Dungarvan Harbour and Waterford Harbour were carried out by walking across the sandflats parallel to the upper edge of the trestles and carefully scanning along each row of trestles. Counts in the northern control sectors at Ballymacoda Bay and Dungarvan Harbour were mainly carried out from the shoreline.

4.63 Counts in the oyster trestle sectors (and control sectors) at Bannow Bay, Castlemaine Harbour and Poulnasherry Bay were carried out from shoreline vantage points. At Bannow Bay and Castlemaine Harbour there was limited visibility of parts of some of the oyster trestle blocks from these vantage points.

4.64 At each site, counters were given detailed instructions about count timing and methodology in order to highlight to the counters site specific features which might otherwise affect count quality (Atkins, 2010a-f). Counts generally began one-two hours before low tide and lasted for around two-four hours, depending on site conditions.

4.65 On each count, the number and activity (feeding or roosting) of all waterbird species in each sector was recorded. Counters also recorded whether birds were on trestles, on the tideline (including birds on the water within around 10 m of the tideline) or on intertidal habitat away from the tideline. Counters also recorded the position of the tideline at the time of the count in each sector (see paragraphs 4.71-4.76).

4.66 In sites with dispersed blocks of oyster trestles (Bannow Bay, Castlemaine Harbour, Dungarvan Harbour and Waterford Harbour), the oyster trestle sectors included areas of intertidal habitat without any trestles. At these sites, counters recorded whether birds were within or outside the trestle blocks in the relevant sectors.

4.67 At Bannow Bay, the oyster trestle sectors were divided into sub-sectors so that birds were recorded separately in each discrete block of sectors. This was designed to allow analysis of potential bias caused by the reduced visibility of some of the trestle blocks.

4.68 At Ballymacoda Bay, during counts in sectors CN2, CN3 and CN4 birds were counted separately in the areas of clear sand and areas of mixed sediment shore.

4.69 Counters also recorded the nature and location of any human activity in the intertidal zone within 200 m of the count sector.

4.70 Counters recorded waterbird count data directly onto standardised waterbird count forms in the field. Separate count forms were used for all counts.

Tideline mapping

4.71 Counters were instructed to map the position of the tideline in each sector at the time of the count. Maps were provided with the count sector boundaries, position of oyster trestles and tidal channels and other features that could assist in mapping the tideline.

4.72 Problems were encountered at two sites.

4.73 At Bannow Bay, the counter felt unable to gauge the position of the tideline with sufficient accuracy to map it. However, observations by Tom Gittings during several low tides in November 2010 indicated that there is little variation in the exposure of the count sectors during low tides of 1.0 m or less, because the intertidal habitat is fully exposed. The exception is Bannow Bay-C1, where there may be some variation in the exposure of the southern end. For this site, it was assumed that the tideline position on each day was the same as that mapped in November 2010.

4.74 At Waterford Harbour, due to tidal restrictions and adverse weather, it was not possible to map the extent of the oyster trestles before the start of the study. On a preliminary visit, we noted that the licensed blocks appeared to at least approximately correspond to the extent of the trestles. Therefore, these blocks were used to define the oyster trestle count sectors. However, subsequent mapping in February 2011 showed that the trestle locations did not correspond exactly to the licensed areas. Therefore, the tideline mapping based on interpreting the oyster trestle sector extents as corresponding to the extent of trestles will have been incorrect.

4.75 To address this problem, we mapped the tideline by GPS in sectors C4-C6 and OY1-OY2 on 16th August 2011 on a 0.7 m low tide, using the same timings relative to low tide as were used in the count carried out on 17th February 2011. The tideline that we mapped is very similar to the tideline positions shown on GoogleEarth imagery for 6th August 2008 and 5th November 2009 (both days with 0.8 m low tides), indicating that this tideline is representative of typical tideline alignments for these type of tidal conditions.

4.76 We used the tideline positions mapped on 16th August 2011 to represent the tideline position during the 17th February 2011 count, and to re-calibrate the tideline positions mapped for sectors C4-C6 and OY1-OY2 on the other counts. For C1, C2 and C7, we have used the tideline positions mapped during the counts, as the configuration of the bays around these sectors should have allowed relatively accurate mapping during the counts.

Data processing

4.77 All count data was entered into Excel spreadsheets and tideline positions were digitised in ArcMap shapefiles. We double-checked the spreadsheet and shapefile data against the original count forms to pick up any errors in data entry. We also screened the data to identify any data entry errors in the raw data recorded on the count forms. For example, we reviewed the tideline position maps to check that the tideline positions recorded followed a logical sequence in relation to time before/after low tide. We checked any potential ambiguities or inconsistencies with the counters.

4.78 Before beginning the main data analyses (the assemblage variation and species analyses), we excluded the following from the bird count datasets: the incomplete second count series from

Dungarvan Harbour and Poulnasherry Bay and third count series from Ballymacoda Bay; the poorly covered sector CN5 at Dungarvan Harbour; sector C2 from Waterford Harbour; and bird counts from the mixed sediment areas of sectors CN2-CN4 at Ballymacoda Bay. These counts were included in the summary tables presented in the *Overview of count data* section.

4.79 We used the tideline positions mapped during each count to clip the sector polygons to produce polygons representing the exposed areas in each sector during each count. We then quantified the length of tideline and the exposed area during each count in each sector and, where appropriate, sub-divisions of the sectors (within and outside oyster trestle blocks for the OY sectors at Bannow Bay, Castlemaine Harbour, Dungarvan Harbour and Waterford Harbour; and areas of clear sand and mixed sediment for sectors CN2-CN4 at Ballymacoda Bay). We excluded the tideline along the Womanagh River channel in sectors CN1 and CS3-CS4 at Ballymacoda Bay, and along the main tidal channel in sectors CS3-CS4 at Dungarvan Harbour from calculations of tideline length. These tidal channels have raised sandy ridges along their banks with steeply shelving sides and do not provide the gradually receding tideline habitat favoured by waders. However, because Wigeon showed a strong association with the Womanagh River channel, we included the tideline along the Womanagh River channel in sectors CN1 and CS3-CS4 at Ballymacoda Bay in the analyses of Wigeon distribution.

Data analysis

4.80 For clarity, data analyses methods are described in the relevant parts of the Results section.

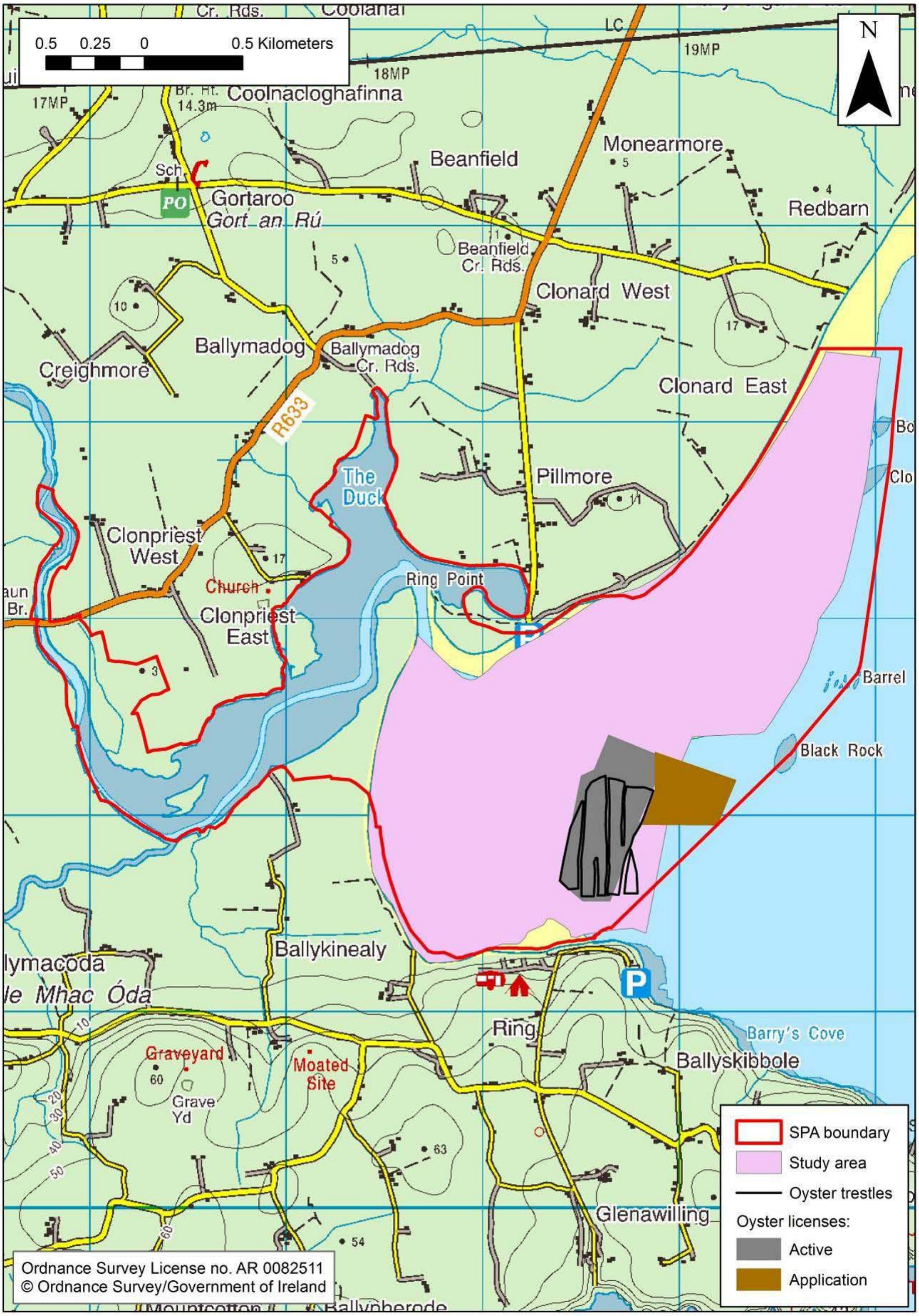


Figure 4.1 – Location of study area and oyster trestles at Ballymacoda Bay.

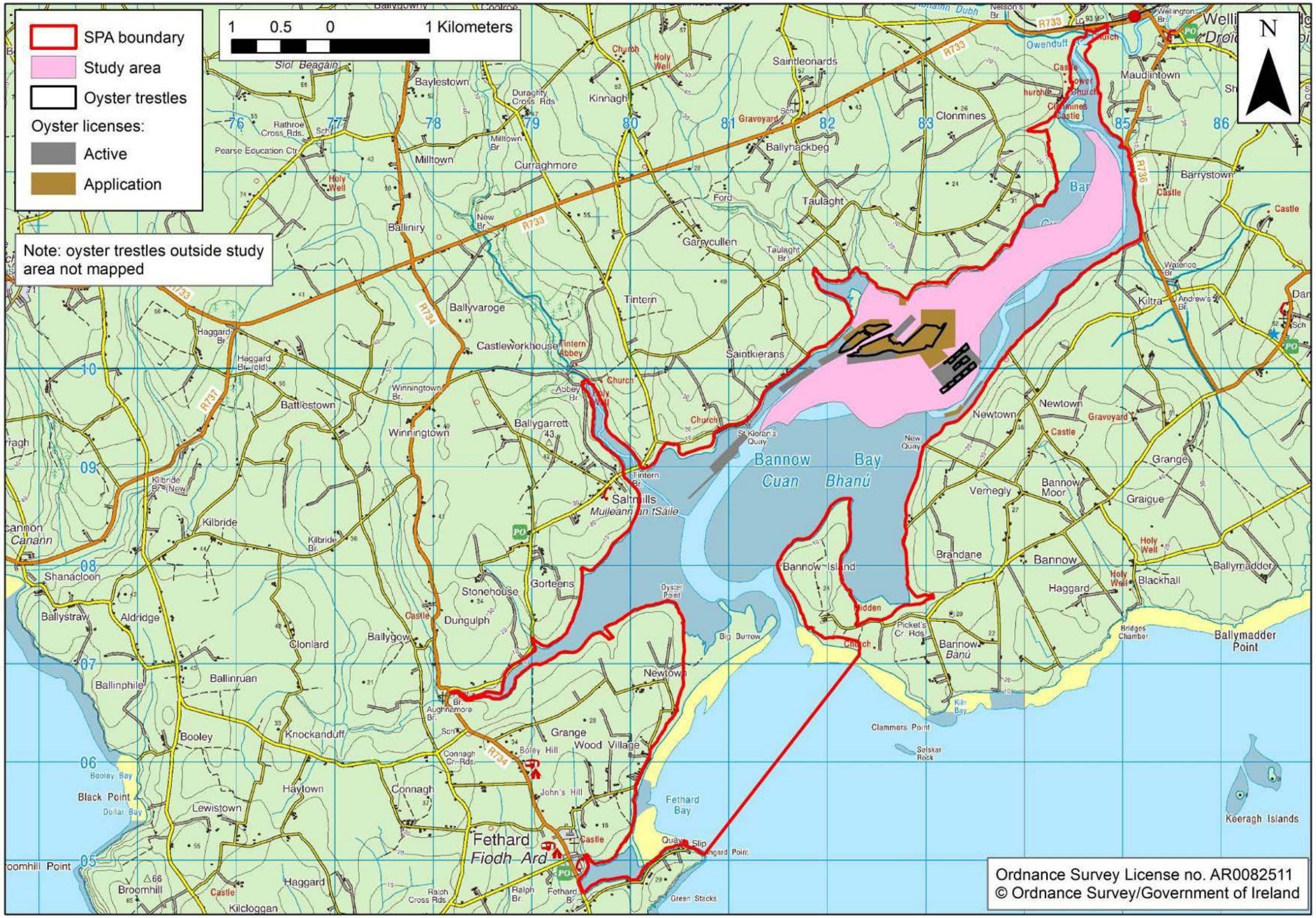


Figure 4.2 - Location of study area and oyster trestles at Bannow Bay.

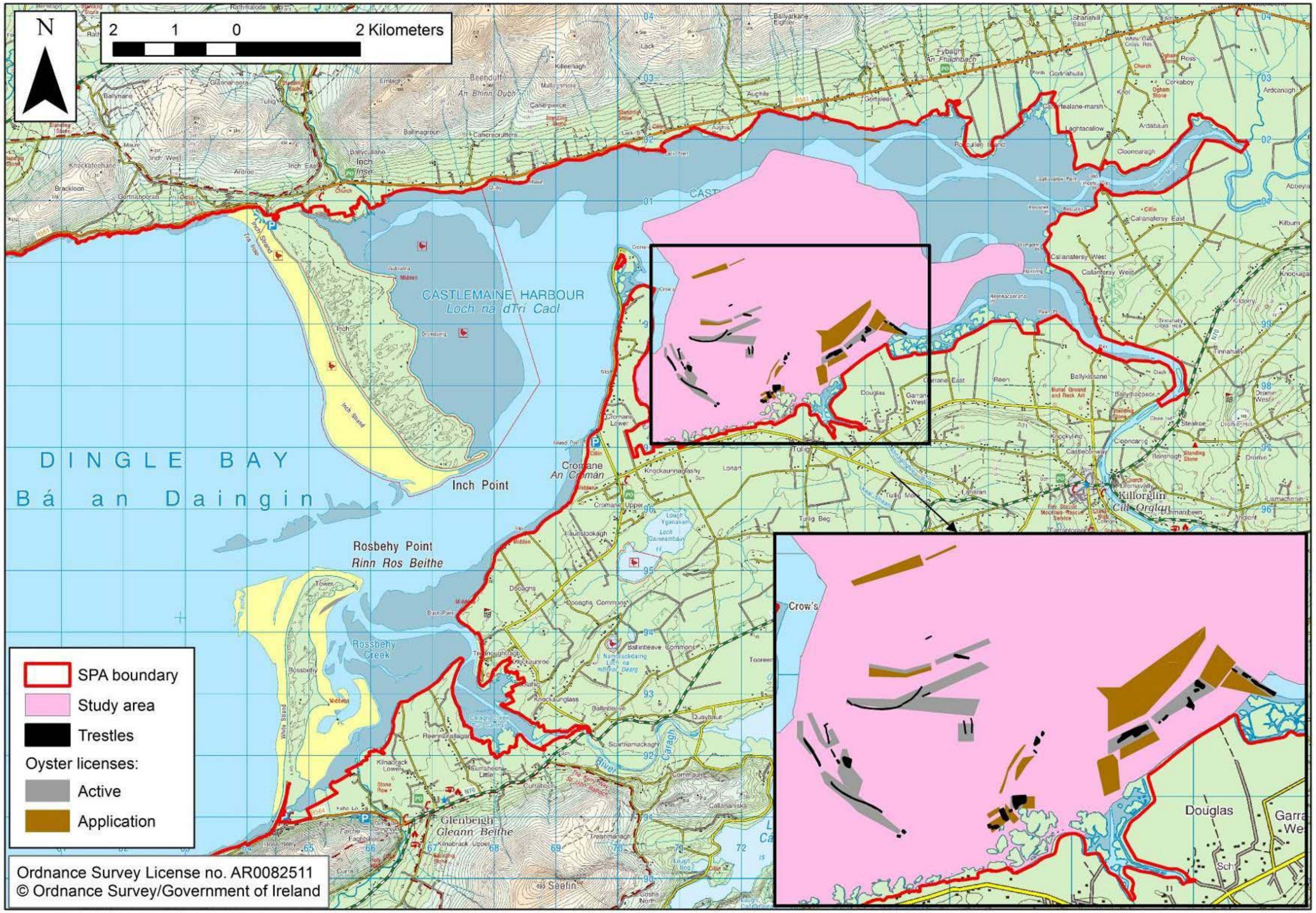


Figure 4.3 - Location of study area and oyster trestles at Castlemaine Harbour.

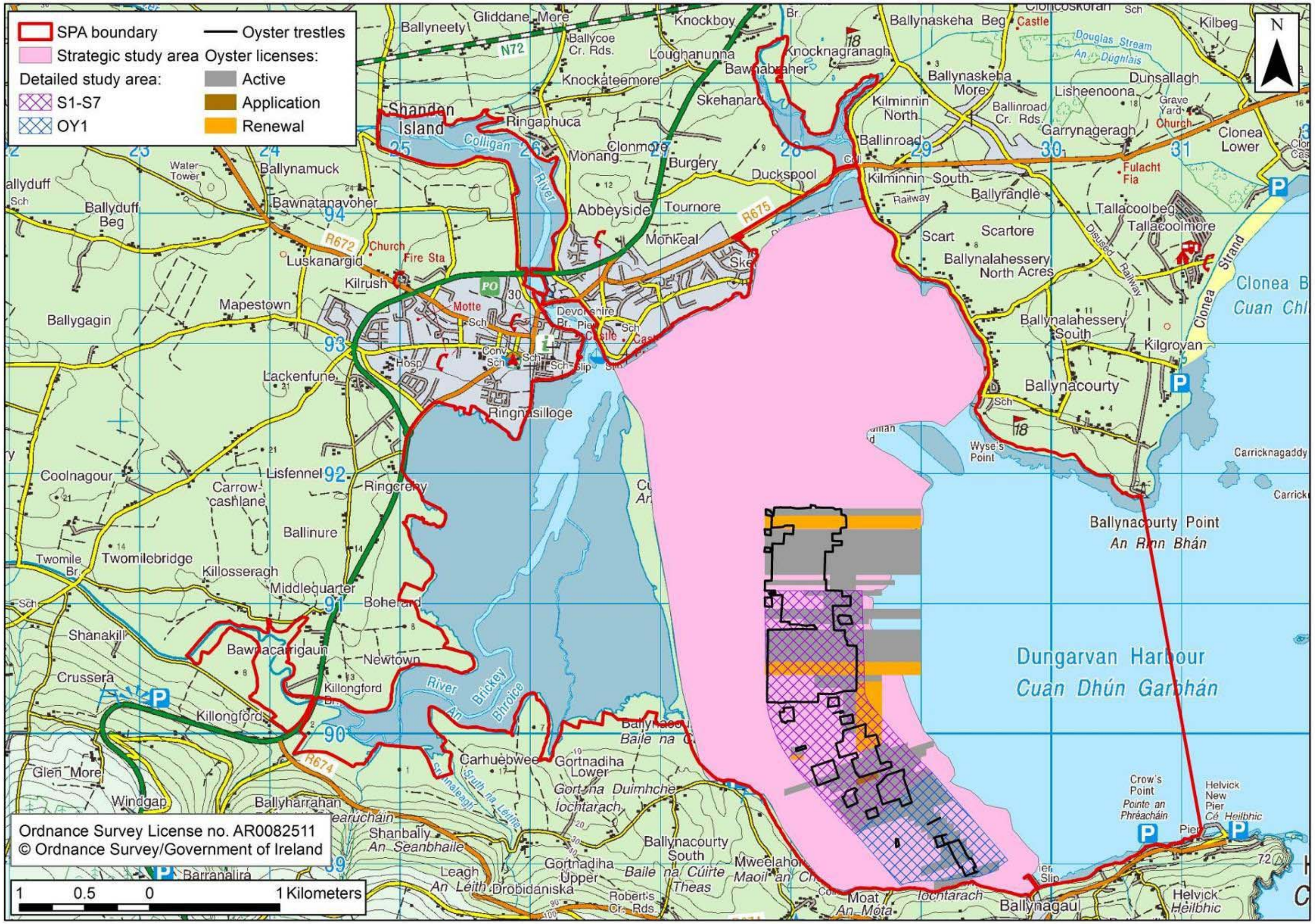


Figure 4.4 - Location of study area and oyster trestles at Dungarvan Harbour.

Figure 4.5 - Location of study area and oyster trestles at Poulnasherry Bay.

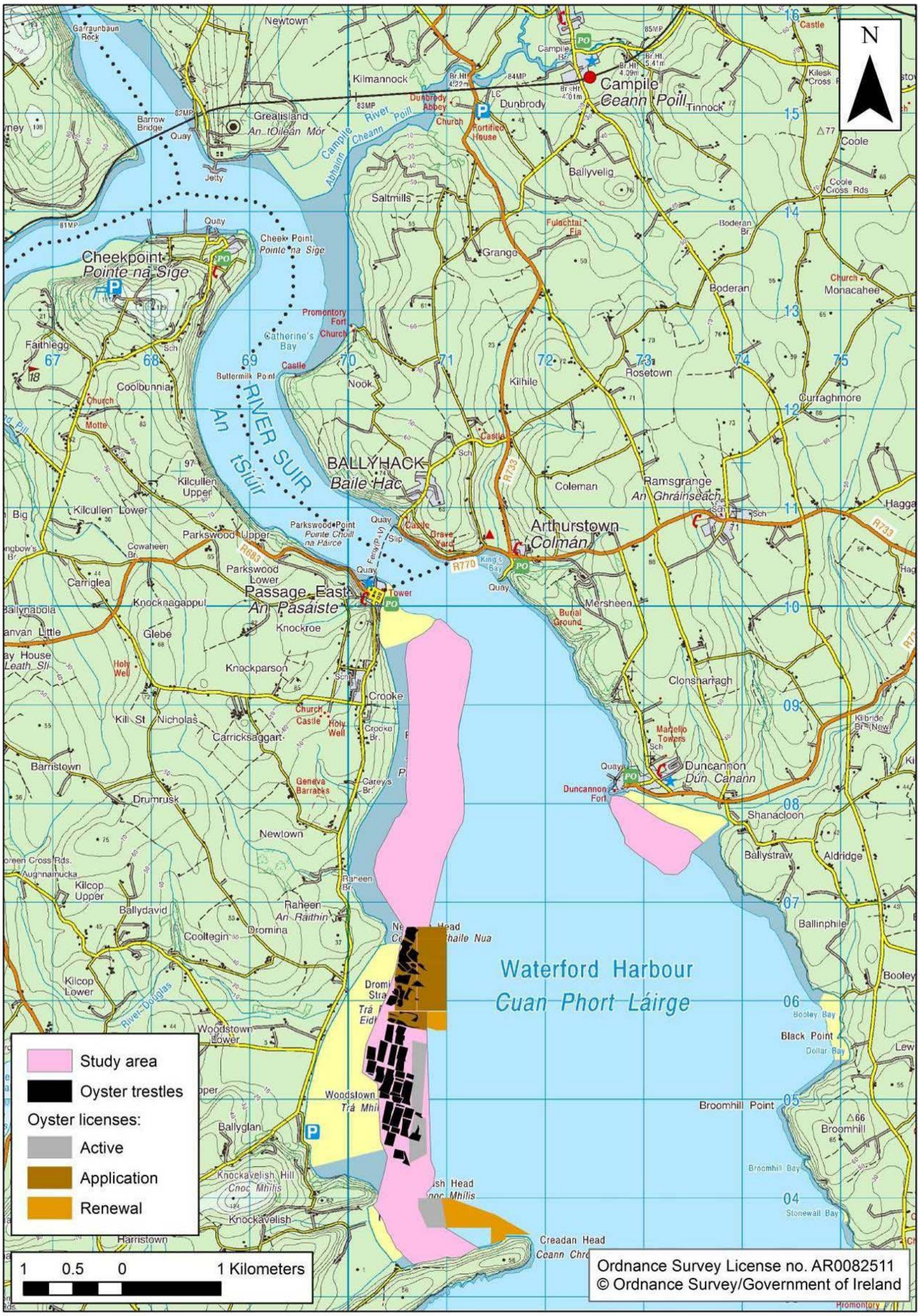


Figure 4.6 - Location of study area and oyster trestles at Waterford Harbour.

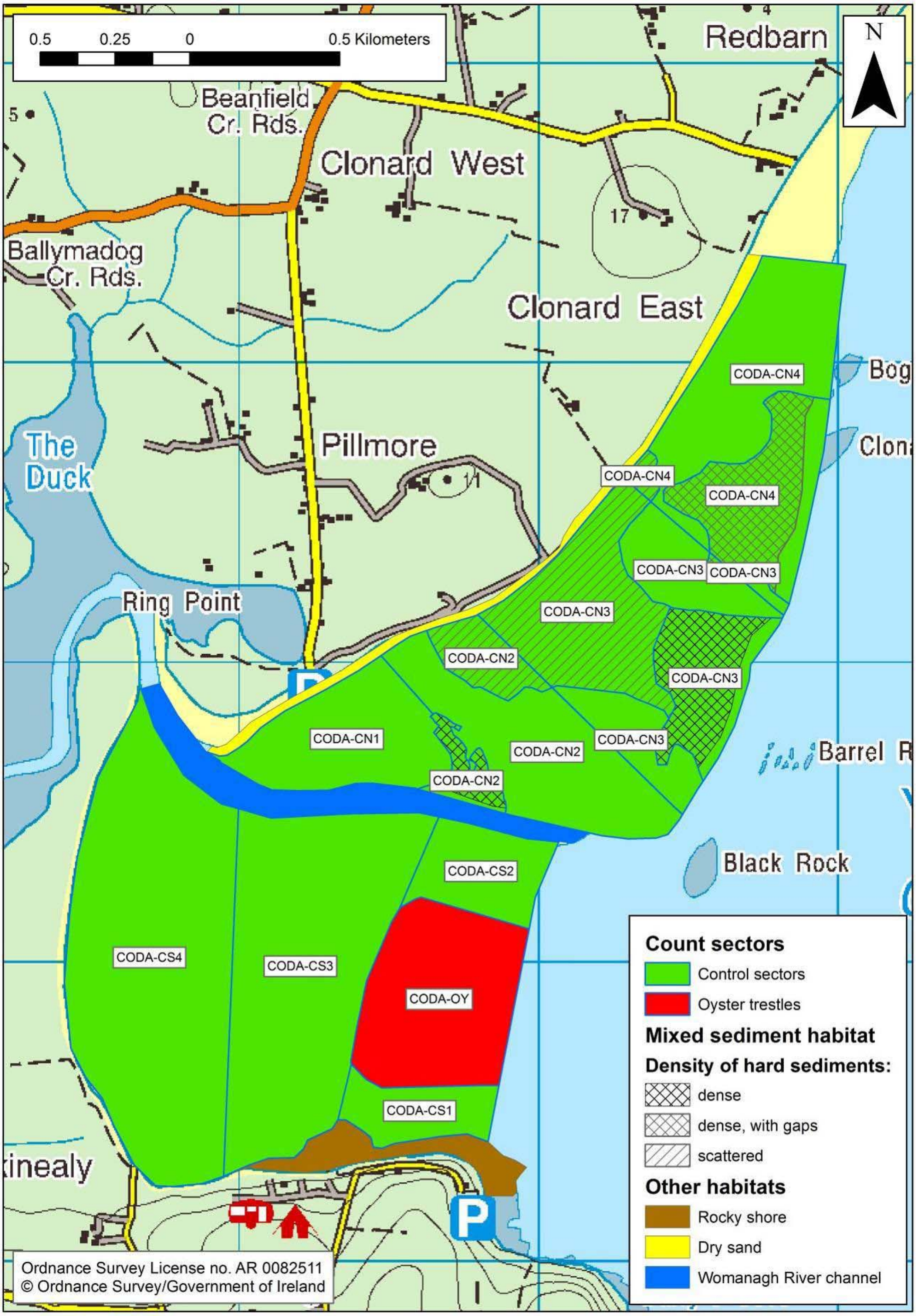


Figure 4.7 – Count sectors at Ballymacoda Bay.

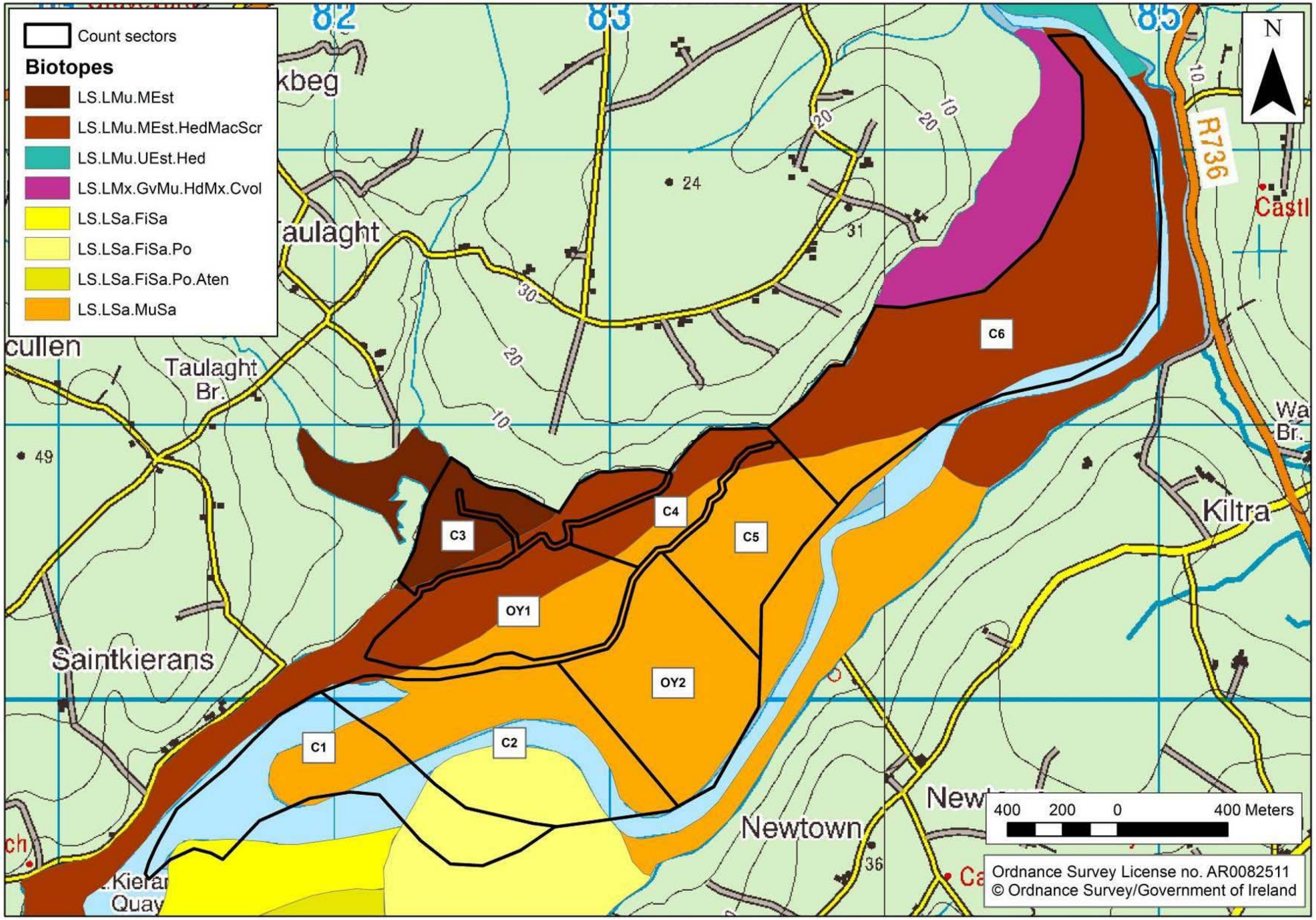


Figure 4.8 – Count sectors at Bannow Bay.

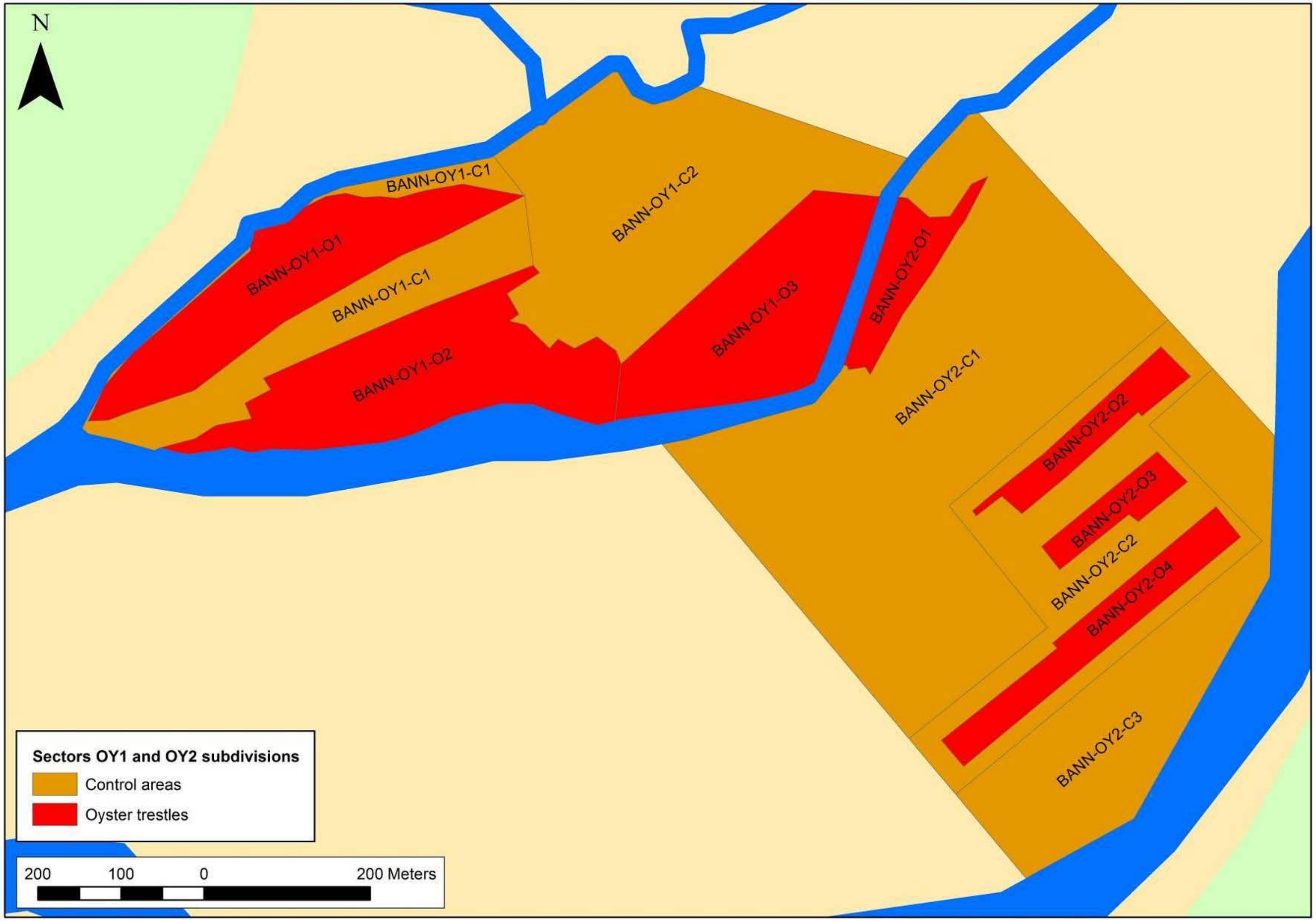


Figure 4.9 – Sub-divisions of OY sectors at Bannow Bay.

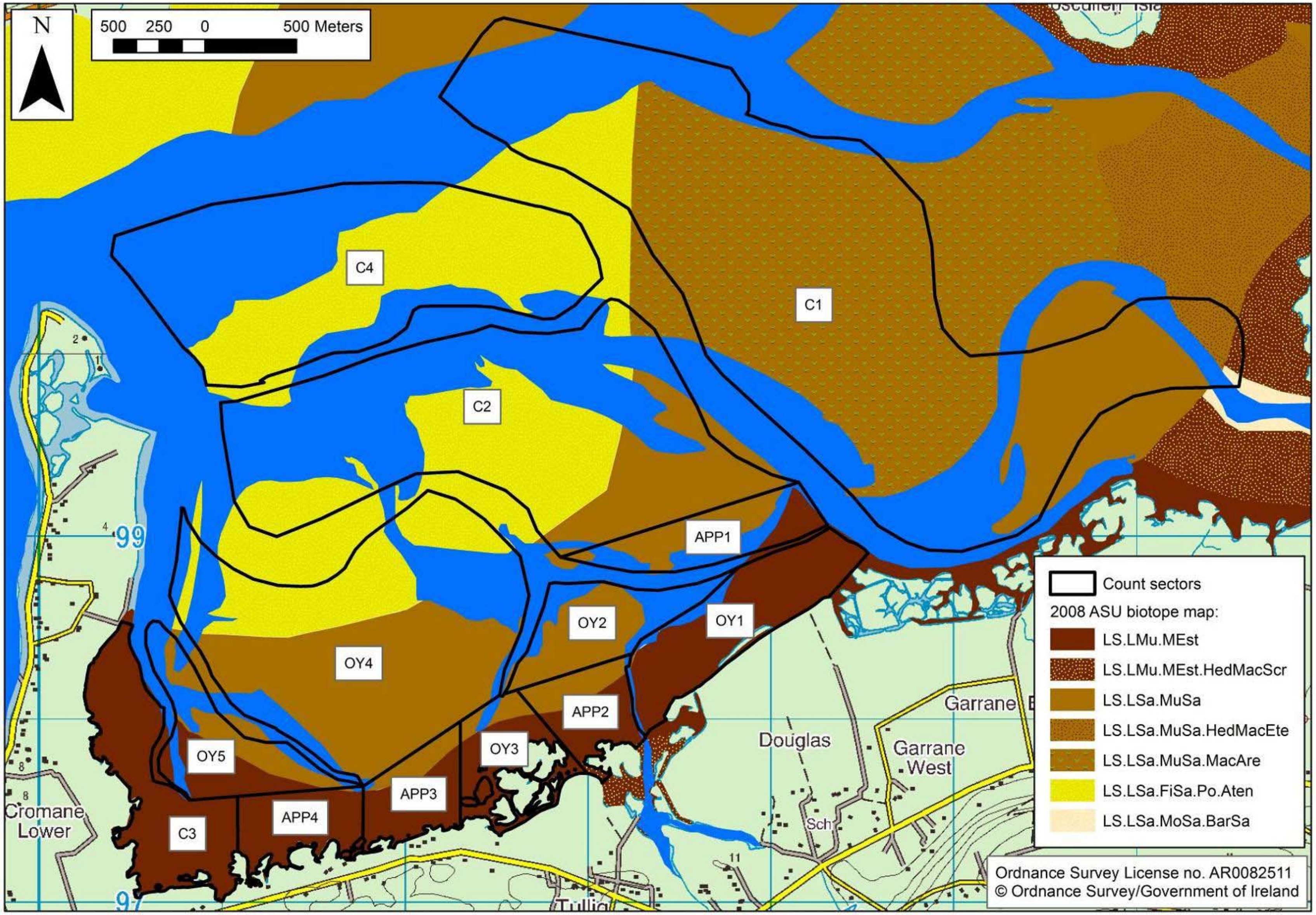


Figure 4.10 – Count sectors at Castlemaine Harbour.

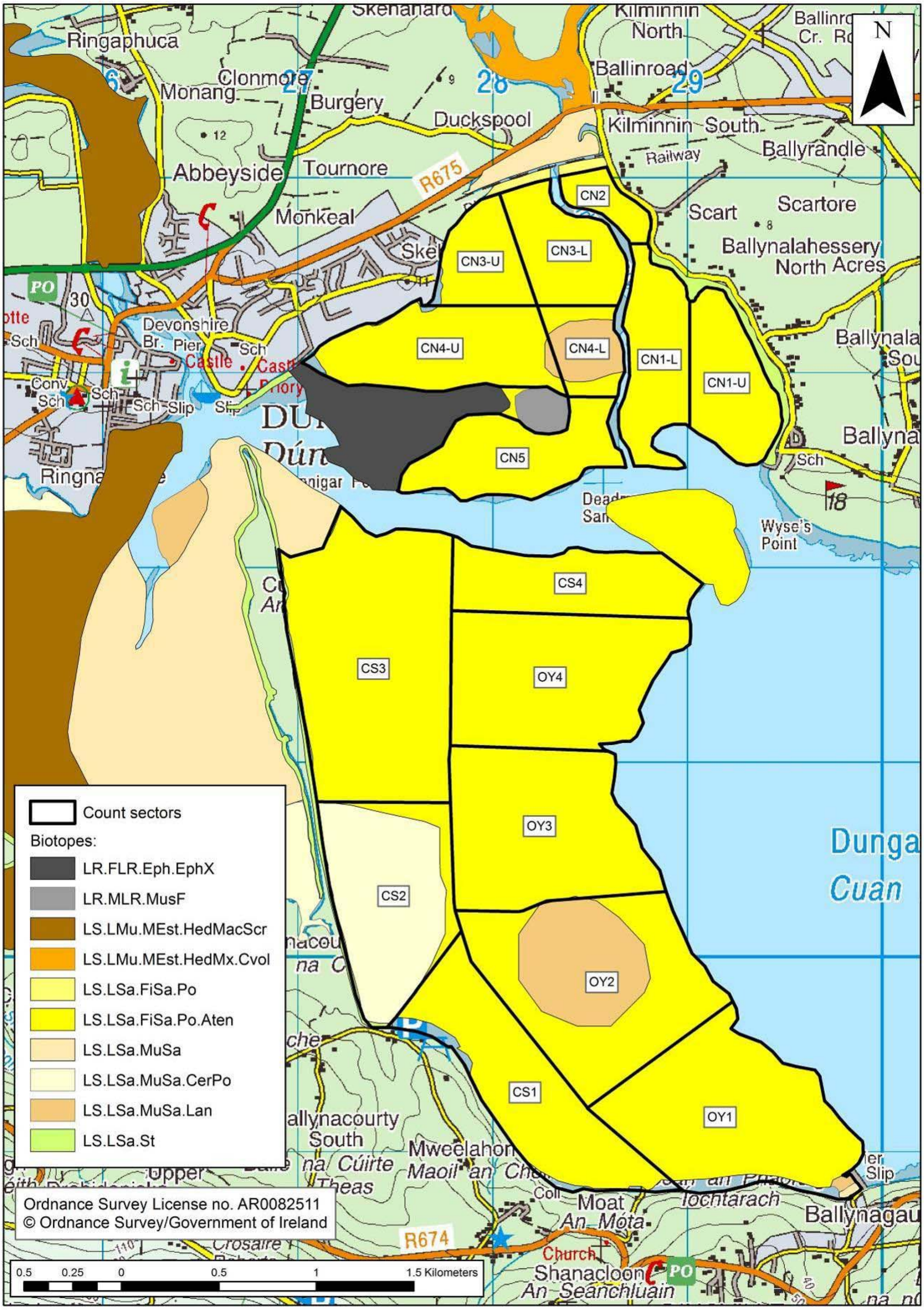


Figure 4.11 – Count sectors at Dungarvan Harbour.

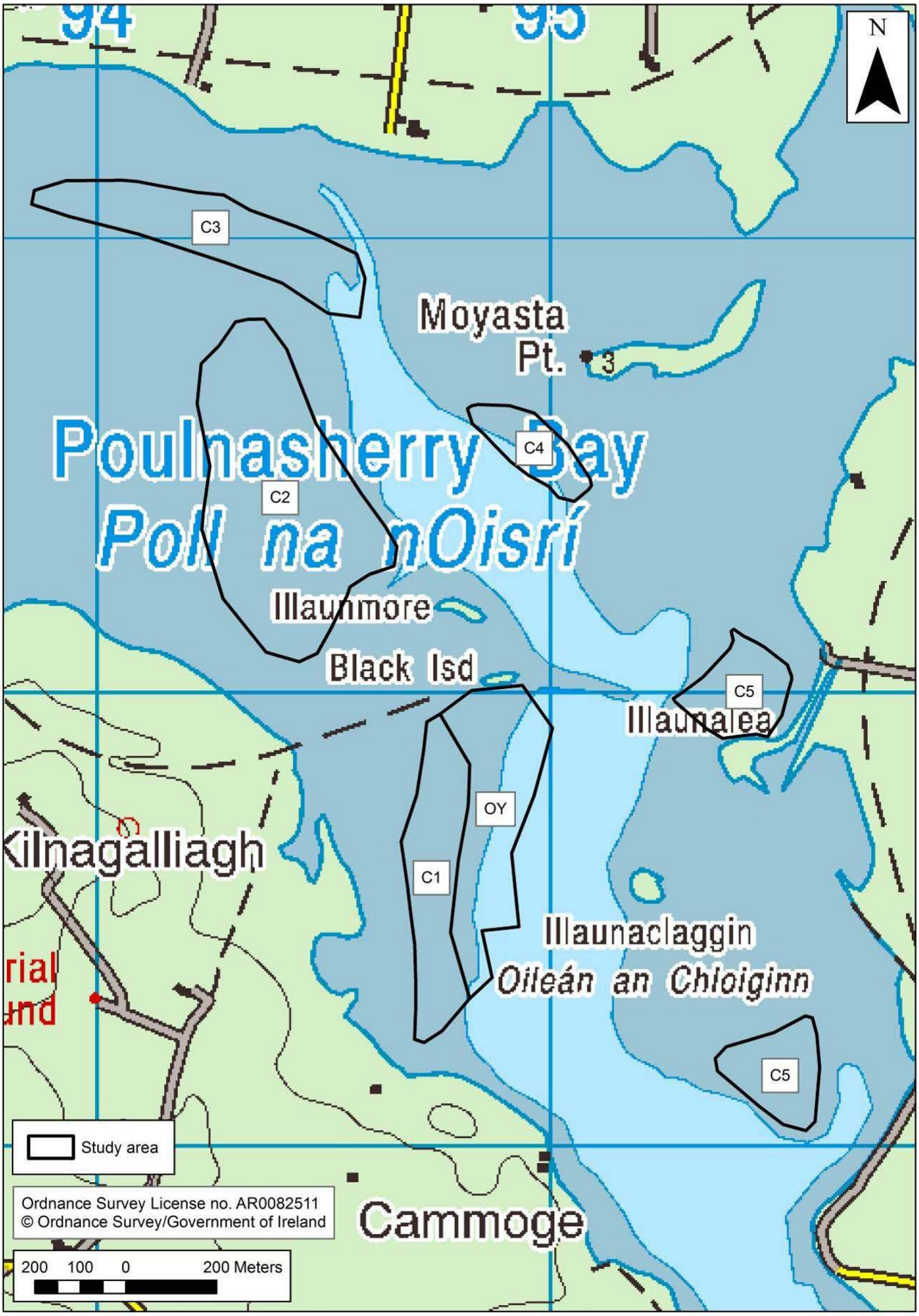


Figure 4.12 – Count sectors at Poulnasherry Bay.

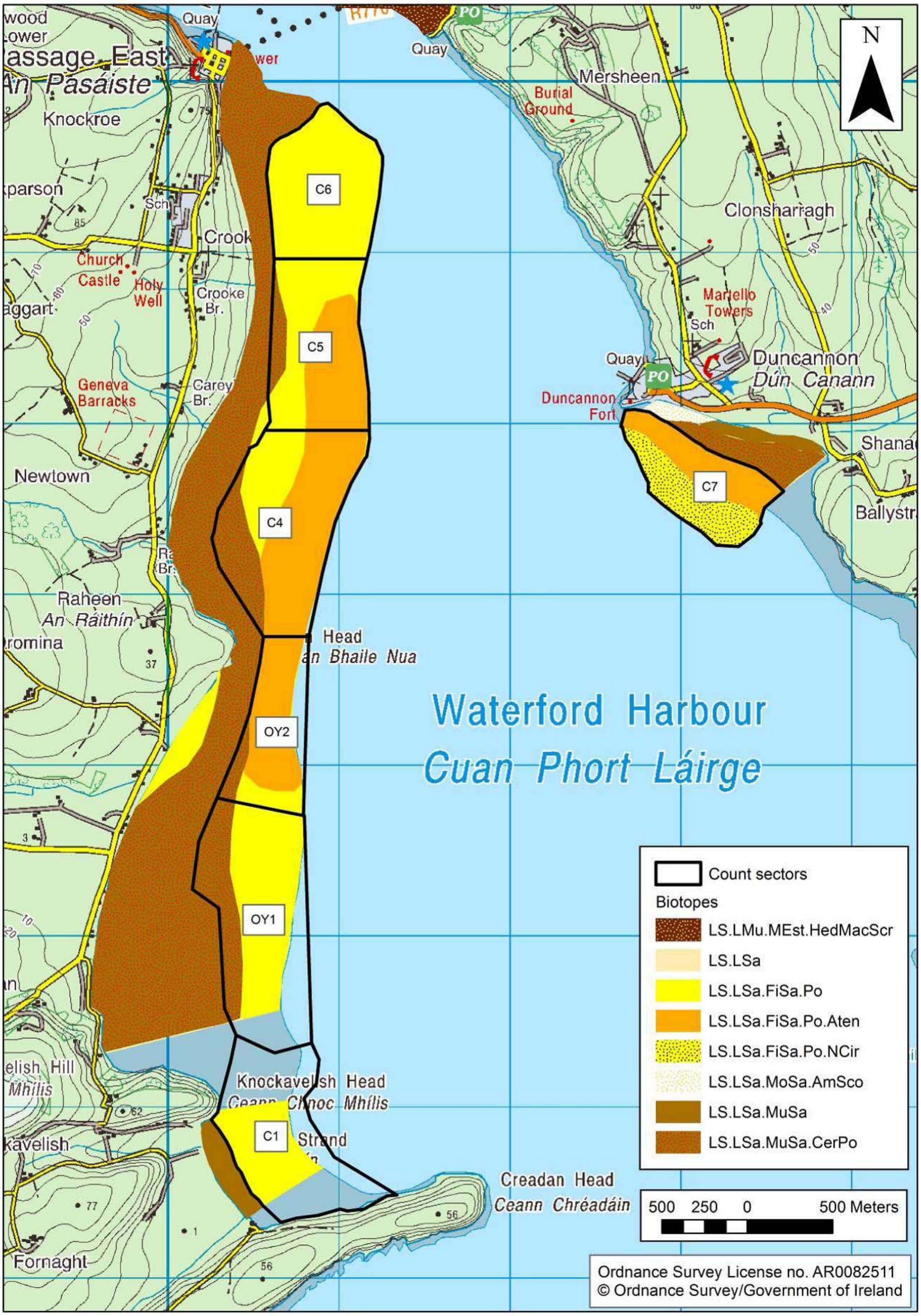


Figure 4.13 – Count sectors at Waterford Harbour.

5. Methods: Intensive study

Study design

5.1 The objective of this study was to contribute to an assessment of whether the spatial distribution of waterbirds is affected by the presence of oyster trestles. In particular, this study aimed to identify whether there were consistent patterns of positive or negative association with oyster trestles within one site with a high level of intertidal oyster culture. This study was complementary to the extensive study: it has more statistical power and better spatial resolution, so potentially confounding effects of lateral position on the shoreline could be taken into account. In addition, the data from this study has been combined with data from the extensive study to provide a larger data series. However, it was limited to one site so the results were not so general.

5.2 The study area was a 2 km stretch of shore at Dungarvan Harbour, Co. Waterford containing a mixture of large blocks of trestles, small blocks of trestles and clear areas. The study area is divided into seven longitudinal sectors (i.e., sectors orientated perpendicular to the shoreline) and five lateral bands (i.e., bands that are parallel to the shoreline).

5.3 On each count day, one or two repeat counts were carried out. Numbers, activity, location (within/outside trestle areas) and position (tideline or intertidal) of birds in each band of each sector were recorded. In addition the tideline position was mapped, and oyster farming and other activities were recorded (by sector and band).

Study site

5.4 This study was carried out at Dungarvan Harbour, Co. Waterford (see paragraphs 4.20-4.23 for a general description of this site). This site was selected for the study because it contains a long stretch of apparently homogeneous shoreline habitat with mixed oyster trestle blocks and clear areas.

5.5 The study area was a 2 km stretch of shoreline (see Figure 4.4), corresponding to the sectors OY2 and OY3 of the extensive study. This area contains a mixture of large blocks of trestles, small blocks of trestles and clear areas. The study area was divided into seven longitudinal sectors (i.e., sectors orientated perpendicular to the shoreline) and five lateral bands (i.e., bands that are parallel to the shoreline) (Figure 5.1).

5.6 We designed the study area so that the tideline passed through each sector with broadly similar timing.

5.7 The landward boundary of the study area was defined by a series of red buoys in the southern section, and by the western edge of the main block of trestles in the northern section. Our observations indicated that the alignment of the red buoys was approximately parallel to the tideline. While the line of red buoys continued slightly to the west of the edge of the main block of trestles, we used the latter as the boundary for practical reasons.

5.8 The count sectors were defined so that they could be clearly identified in the field using existing features such as buoys and the configuration of the trestle blocks. This meant that sectors were not of equal size.

5.9 The lateral bands were each 150 m wide. The configuration of the trestle blocks and the arrangement of the lanes within the main trestle block were used to identify the boundaries of the lateral bands in the field.

5.10 We excluded sector OY1 from the study because the tideline behaves differently in this sector, with a number of raised sandbars separated by deep channels appearing at low tide. However, counts of this sector were carried out on some of the count days, as additional counts to the main study.

Waterbird counts

5.11 All waterbird counts for this study were carried out by Tom Gittings. Counts were carried out on eight dates during January-March 2011 (Table 5.1). On each date, one or two complete counts were carried out, with a total of 13 complete counts being achieved. However, during the second count on 24th January the tideline was rapidly advancing through the upper lateral bands during the latter part of the count, and birds were being displaced into the shoreline zone above the study area. Therefore, this count was excluded from the main analyses.

5.12 Counts were carried during moderate spring low tide conditions (low tides of 0.4-0.7 m) when the oyster trestles were more or less fully exposed, but the tideline remained within the lateral bands. Weather conditions were generally good during the counts, and visibility was good during all counts (Table 5.1).

Table 5.1 – Details of the timing of the intensive study counts and low tide and weather conditions during the counts.

Date	Count	Low tide[1]		Count times[2]		Starting sector	OY1 included?	Weather		
		Time	Height	Start	Finish			Cloud cover[3]	Wind[4]	Rain[5]
05 Jan	1	12:25	0.6 m	10:35	12:12	S1	No	1	SW2-3	1
	2			12:20	14:06	S7	No	1	SW3	1
20 Jan	1	12:05	0.4 m	09:45	11:58	S1	No	1-2	E-SE 0-2	1
	2			12:14	14:05	S7	No	1	E2	1
21 Jan	1	12:48	0.4 m	10:41	12:52	S7	No	1	W1	1
24 Jan	1	14:59	0.5 m	12:45	14:45	S7	Yes	1	W3	3
	2[6]			15:50	17:26	S1	No	1	NW3-4	3
01 Feb	1	10:53	0.7 m	08:53	10:58	S1	Yes	1	W-NW 1-2	1
	1			11:04	12:46	S7	Yes	1	NW2	1
17 Feb	1	11:01	0.5 m	09:21	11:38	S1	Yes	2-3	W-NW 1-2	1
23 Feb	1	15:20	0.5 m	13:28	15:13	S1	Yes	1-2	SW3	1
07 Mar	1	13:06	0.6 m	11:13	13:05	S7	Yes	3	E2-3	1
	2			13:34	14:59	S1	No	3	E2	1

[1] source: Admiralty EasyTide (http://easytide.ukho.gov.uk/)
[2] times do not include OY1
[3] 1 = 0-33%, 2 = 33-66%, 3 = 66-100%
[4] Beaufort scale and direction
[5] 1 = none, 2 = showers, 3 = drizzle
[6] count not included in main analyses (see text)

5.13 The first count on each day was started when the tideline had reached at least the middle of band B, and when there were not any large flocks of waterbirds (excluding gulls) in the shoreline zone above the study area (i.e., in the area corresponding to the relevant parts of sectors CS1 to CS3 of the extensive study). Excluding sector OY1, the first count generally began 100-150 minutes before low tide, the second count began within 30 minutes after low tide and counts lasted around 100-140 minutes.

5.14 The counts were begun by walking parallel to the upper edge of the study area, keeping around 200 m back from any significant bird activity. As the tideline moved through the study area the counter moved into the study area, again keeping around 200 m back from any significant bird activity and taking care to avoid disturbance of birds, where possible. On most counts, it was necessary to walk through part, or all, of the main block of trestles, using the north-south lanes. It was not possible to completely avoid disturbing birds while doing this, but numbers disturbed were generally small and the birds generally re-settled nearby. Care was taken to keep track of these movements and avoid double-counting.

5.15 Counts within the trestle blocks were carried out by carefully scanning along each row of trestles.

5.16 On each count, the number and activity (feeding or roosting) of all bird species was recorded separately for each lateral band of sector was recorded. The counter also recorded whether the birds were within or outside trestle blocks and whether birds were on the tideline (including birds on the water within around 10 m of the tideline) or on intertidal habitat away from the tideline.

5.17 The counter also recorded the position of the tideline at the time of the count in each sector and estimated the percentage of each lateral band of each sector that was shallowly or deeply flooded.

5.18 The counter recorded the nature and location of any human activity in the intertidal zone within 200 m of each sector during the period that each sector was counted. The position of the activity was sketched on a map and the number of vehicles, people and animals (as appropriate) was recorded). When the activity began after the relevant part of the sector had been counted (e.g., a tractor arrived during the count), this was noted. In addition, at intervals throughout the count, the total number of tractors on the beach was recorded to provide an overall index of the level of husbandry activity.

5.19 All count data was recorded using a custom-designed notebook with forms for recording waterbird counts, shallow and deep flooding, and tractor counts, and maps for recording tideline position and disturbance (see Appendix D).

Data processing

5.20 Bird and tractor counts and flooding data were entered directly from the field notebooks into Excel spreadsheets. Data on the spatial extent of disturbance and tideline positions were redrawn onto A4 sized maps, and the tideline positions were digitised in ArcMap shapefiles. Notes on disturbance events were transcribed onto disturbance recording forms.

5.21 We double-checked the spreadsheet and shapefile data against the original count forms to pick up any errors in data entry. We also screened the data to identify any data entry errors in the raw data recorded on the count forms. For example, we reviewed the tideline position maps to check that the tideline positions recorded followed a logical sequence in relation to time before/after low tide.

5.22 We used the tideline positions mapped during each count to clip the sector-band polygons to produce polygons representing the exposed areas in each band of each sector during each count. We then quantified the length of tideline and the exposed area during each count in each band of each sector.

Data analysis

5.23 For clarity, data analyses methods are described in the relevant parts of the Results section.

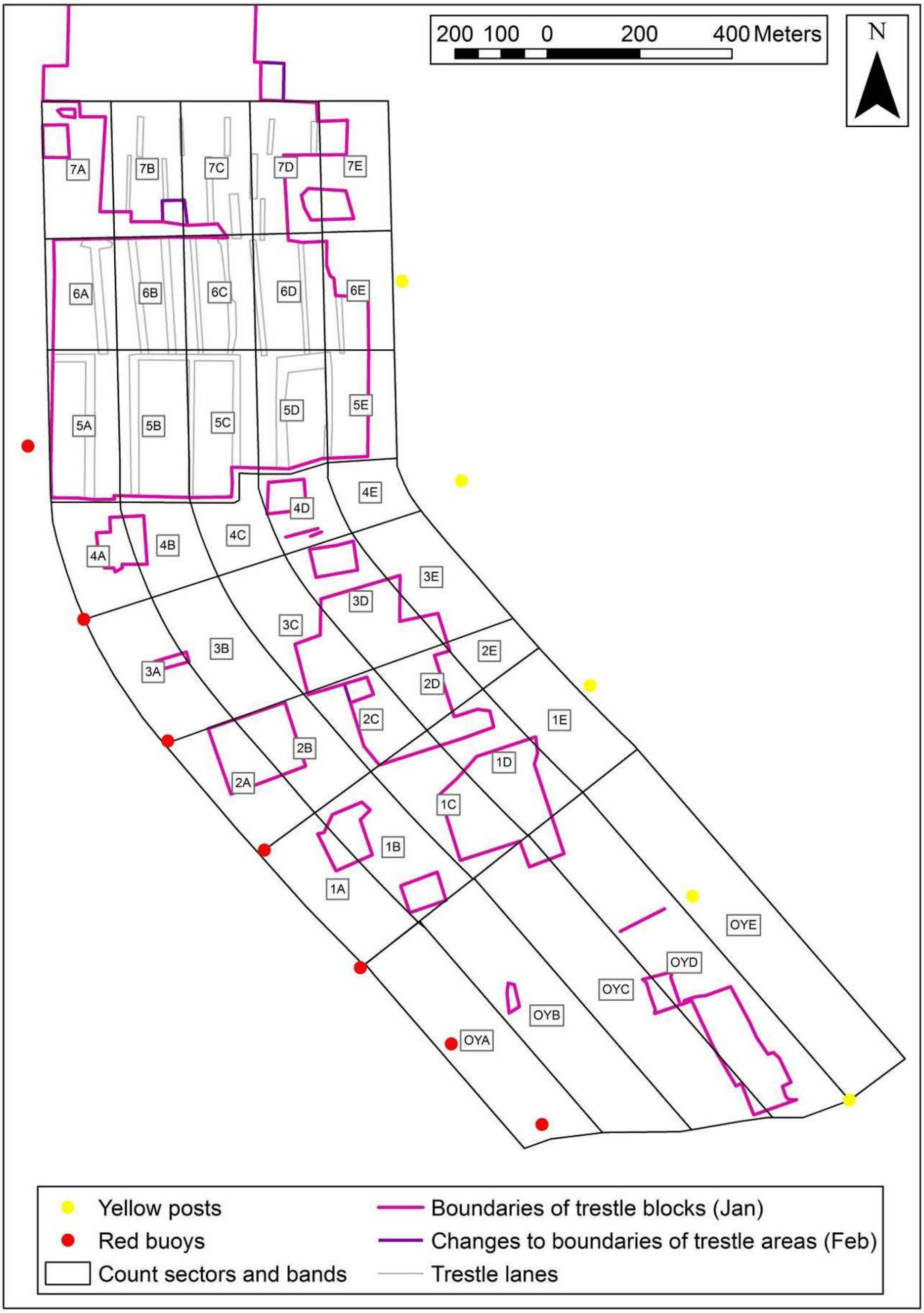


Figure 5.1 – Count sectors used in the intensive study at Dungarvan Harbour.

6. Results: Extensive study

Factors potentially affecting count accuracy

Disturbance

6.1 Across all the sites, count days and count series in the main dataset (a total of 269 sector counts), 17 sector counts were recorded by the counters as being affected by disturbance (Table 6.1). Of these, nine were on the first count day and may reflect lack of clarity in the original instructions about categorising counts affected by disturbance. Following this count day, counters were instructed to only record counts as being affected by disturbance if the disturbance caused displacement of birds from the sector being counted. So if disturbance flushed birds but they re-settled within the sector then the counters were instructed to not record the count as being affected by disturbance. Following this clarification, the number of sector counts recorded as being affected by disturbance reduced from nine in the first count to seven over the next three counts (2.3 per count), with one sector count also recorded as affected by disturbance in the additional fifth count at Dungarvan.

6.2 Displacement of birds from sectors due to disturbance was only recorded twice: at Ballymacoda Bay in sector CN2 during the second count on the second count day, and at Dungarvan Harbour in sector CS3 during the third count day (Table 6.1). In both cases, the numbers of birds involved were relatively small and the displacement was unlikely to have significantly affected the overall count.

Detectability

6.3 At some sites, the configuration of the site and/or access issues meant that visibility of some sectors was limited. Sectors C1 at Castlemaine Harbour and CN5 at Dungarvan Harbour have been excluded from the main analyses for reasons discussed already (see paragraphs 4.49 and 4.53).

6.4 At Bannow Bay, there was poor visibility of some of the oyster trestle blocks from the shoreline vantage points. The OY sectors were sub-divided to allow separate counting of discrete groups of oyster trestle blocks. In sector OY1, there was good visibility of the trestle blocks in sub-division O1, moderate visibility in sub-division O2 and poor visibility in sub-division O3. These three sub-divisions had similar areas and lengths of tideline. In sector OY2, there was good visibility of the trestle blocks in sub-division O2-O4 and poor visibility in sub-division O1. Sub-division O1 had a smaller area than sub-divisions O2-O4, but had a tideline edge unlike the other sub-divisions. Bird counts in all the trestle block sub-divisions were low, but the data does not show any obvious indications of lower numbers in the sub-divisions with poorer visibility (Table 6.2 and Table 6.3).

6.5 At Castlemaine Harbour, there was poor visibility sector of sector OY3. Bird counts within and outside the trestle blocks were relatively low, taking account of the available habitat, compared to counts in the other upper shore sectors (APP1-APP4, C3 and OY1-OY2) (Table 6.4 and Table 6.5). However, because of the small size of the sector, and the low overall number of birds recorded within oyster trestle blocks, it is unlikely that undercounting in sector OY3 will have significantly biased the results. For example, taking the four most numerous and apparently undercounted species in Table 6.5 (Oystercatcher, Curlew, Redshank and Black-headed Gull), correcting for the apparent undercounting would only increase the total overall count by around 2-3%.

6.6 At Dungarvan Harbour, during the fourth and fifth count days, unidentifiable waders were seen in the tideline section of sector CN4: 21 Knot or Redshank on the fourth count day and 30 probable Dunlin or Redshank on the fifth count day.

6.7 During counts at Dungarvan Harbour, and during visits to other sites, we noted that distant Turnstones on oyster trestles could be difficult to detect particularly when they were roosting. Therefore, Turnstones within oyster trestle blocks may have been undercounted, particularly in the sites with large blocks of trestles.

Weather conditions

6.8 Weather conditions during some counts were not optimal (see paragraph 4.61). However, none of the counters noted any counts as being significantly affected by weather conditions.

Table 6.1 – Counts affected by disturbance.

Site	Count day	Count series	Sector	Count series	Notes
Bannow Bay	1	1	OY1	1	Tractors working.
Castlemaine Harbour	1	1	OY4	1	Considerable disturbance by dog in NW section. Some trestles empty, some covered by tide by time this area was counted.
	1	1	OY5	1	Recorded as affected by disturbance, but notes on disturbance form indicated that no birds were disturbed.
Ballymacoda Bay	1	1	OY	1 and 2	Tractor and two men working in this sector. No movement of birds was observed that could be related to the workers activities, but it is likely that they were deterring some birds. No birds were seen within at least 50 m of where they were operating.
	2	2	CN2	2	Coastguard helicopter briefly disturbed birds from CN3 into CN2. Some circled back to CN3. Disturbed approximately 50-60 birds.
Dungarvan Harbour	2	1	CN1	1	Three horses ridden in CN2 disturbed BH and CM.
	3	1	CN4	1	Heron flying over.
	3	1	CS3	1	33 DN, 2 SS and 4 GB present 10 mins before start of count. 24 DN flew north crossing over to the northern side of the tidal channel at 10:05 (not flushed). The remaining birds were flushed by horses just before the start of the count and flew south out of the sector.
Poulnasherry Bay	1	1	C1 and OY1	1	Oyster worker with car and trailer. Minor disturbance only.
	1	1	C2	1	Two winkle pickers were working during the whole count just to the north of the count area but had no apparent influence on the birds counted.
	1	1	C6	1	Two winkle pickers with bikes returning from bay past count area. Minor disturbance.
	2	1	OY	1	Minor disturbance from tractor, trailer and two workers at trestles. These left causeway at 11:00 and returned at 11:33.
Waterford Harbour	1	1	C7	1	Ponies, walkers and bait digger caused disturbance
	2	1	OY2	1	
	3	1	OY2	1	
	4	1	OY2	1	

Table 6.2 – Bird counts in the oyster trestle block sub-divisions of sector OY1 at Bannow Bay.

Species	Count day 1			Count day 2			Count day 3			Count day 4		
	O1	O2	O3	O1	O2	O3	O1	O2	O3	O1	O2	O3
Light-bellied Brent Goose											2	7
Shelduck			2						4			
Wigeon	2									4	20	3
Grey Heron	1	1						1				
Oystercatcher	3	1	6	2	2	2		1	2	2	2	6
Bar-tailed Godwit	2	2	2	7	7		2	2			13	
Curlew	1		2	1				2				
Greenshank							1	1		1	2	
Redshank			1				2			1		
Turnstone							3			1		
Black-headed Gull		1		5	4		2	3			1	
Common Gull				1	1							
Herring Gull	1	2						1		3	3	1
Hooded Crow		1	1		2	1		2	6	1	2	

Table 6.3 - Bird counts in the oyster trestle block sub-divisions of sector OY2 at Bannow Bay.

Species	Count day 1				Count day 2				Count day 3				Count day 4			
	O1	O2	O3	O4	O1	O2	O3	O4	O1	O2	O3	O4	O1	O2	O3	O4
Wigeon															2	
Oystercatcher	1	2		2					2			1	1	2	1	
Curlew	1	2			4	2		1	1			2		1		
Redshank				3	1							1				
Black-headed Gull														3		
Lesser Black-backed Gull													3			
Herring Gull				2					1							
Hooded Crow				1									3			

Table 6.4 - Bird counts in the oyster trestle blocks in sectors OY1-OY3 at Castlemaine Harbour.

Species	Count day 1			Count day 2			Count day 3			Count day 4		
	OY1	OY2	OY3	OY1	OY2	OY3	OY1	OY2	OY3	OY1	OY2	OY3
Available habitat												
Area (ha)	1.2	0.2	1.4	1.2	0.2	1.3	1.2	0.2	1.4	0.3	0.1	1.4
Tideline (m)	51	74	0	59	73	25	55	69	0	317	63	44
Bird counts												
Wigeon				2						2		
Mallard				4	2			2		2	9	
Cormorant											1	
Little Egret	1		2									
Grey Heron		2	1		1							
Oystercatcher	7	4		5				1	3			8
Black-tailed Godwit		1										
Curlew	6	2	6	10	1		3	2	3		2	
Greenshank				1								
Redshank	10	1	2	1	2	1	2	1				
Turnstone	7	10				3	5				16	
Black-headed Gull		6		14	3	3	2			3	1	2
Common Gull	3	3		9	1			4		2	1	
Herring Gull	2	2	6		1			1				
Great Black-backed Gull		3						1			1	
Hooded Crow	15	9		4	1	6		5	4	10	5	4

Table 6.5 – Comparison of mean counts in eastern (APP1-APP2 and OY1-OY2), western (APP3-APP4 and C3) and OY3 upper shore sectors outside oyster trestle blocks.

Species	Mean			SD			n > 0		
	East	West	OY3	East	West	OY3	East	West	OY3
Available habitat									
Tideline	3560	2110	636	159	319	663			
Area	103	92	19	1.6	4.0	1.8			
Bird counts									
Light-bellied Brent Goose	44.5	5	8.25	47.7	7.6	7.9	4	2	3
Shelduck	2.75	15.5	1	2.5	16.7	2.0	3	4	1
Wigeon	23.75	14	2	12.7	1.8	4.0	4	4	1
Teal	16.75	5	1	9.9	7.6	2.0	4	2	1
Mallard	22	18.75	6.25	9.6	4.4	2.1	4	4	4
Cormorant	1.75	1	0	1.7	1.2	0.0	3	2	0
Little Egret	1.25	0.75	0	1.5	1.0	0.0	2	2	0
Grey Heron	2.75	2.5	0.5	3.1	1.9	1.0	3	4	1
Oystercatcher	18	34.75	3	15.4	16.3	2.4	3	4	3
Grey Plover	4.25	1.5	0	5.0	1.9	0.0	3	2	0
Lapwing	7.25	10.25	0	9.4	15.1	0.0	3	2	0
Dunlin	27.5	26.25	0	24.2	30.9	0.0	4	2	0
Black-tailed Godwit	16	11.75	0	12.8	8.4	0.0	3	4	0
Curlew	28.75	30.75	4	11.7	19.3	2.2	4	4	4
Greenshank	4.75	3.75	0	3.1	1.7	0.0	4	4	0
Redshank	38.75	35.5	2.5	31.8	24.9	3.8	4	4	2
Turnstone	8.75	9.25	1	5.0	8.5	2.0	4	3	1
Black-headed Gull	38.5	51.25	0	32.2	43.4	0.0	4	4	0
Common Gull	8.5	13	0.75	6.2	8.2	1.5	4	4	1
Herring Gull	9	7.75	0	7.9	6.0	0.0	4	4	0
Great Black-backed Gull	7	7.5	0.5	6.8	3.7	1.0	3	4	1
Hooded Crow	15.5	15.25	1	2.6	7.7	1.2	4	4	2

Species with less than three non-zero counts in each sector group not included.

Overview of count data

6.9 Total counts on each count day at each site are shown in Appendix E. A total of 41 species were recorded across all the sites (Table 6.6). Oystercatcher, Curlew, Redshank, Black-headed Gull and Herring Gull were the only species that occurred in all of the main counts at all the sites, although Oystercatcher and Herring Gull only occurred in very low numbers at Poulnasherry Bay. Common Gull and Hooded Crow occurred in all but one of the main counts, although Hooded Crow only occurred in very low numbers at three of the sites. Light-bellied Brent Goose, Grey Plover, Dunlin and Greenshank occurred regularly in five of the sites, although Greenshank only occurred in low numbers.

6.10 A period of severe weather occurred in November-December 2010 and had just ended when the first counts for this study were carried out. Because there were only four or five count days per site, it is not possible to reliably detect changes in abundances of individual species across the study period that might indicate cold weather movements. However, overall numbers across the range of species at each site did not indicate unusually high or low numbers during the first count period. Numbers at Castlemaine Harbour were low across a range of species on the last count.

6.11 The percentage occurrence on the tideline varied considerably between sites (Table 6.7). At Bannow Bay, the distributions of most species were concentrated on the tideline, while at Ballymacoda and Castlemaine Harbour most species occurred in low numbers on the tideline (except for Light-bellied Brent Goose and Wigeon).

6.12 For most species at most sites, two-thirds or more of the birds recorded were feeding, with particularly high percentages at Castlemaine Harbour (Table 6.8). The exceptions were Cormorant, Golden Plover, Lapwing and some of the gull species at some of the sites. The non-feeding Cormorants were roosting on oyster trestles while the Golden Plover, Lapwing and of the gull species were roosting on sandflats.

6.13 A total of 20 species were recorded on trestles during the main counts (Table 6.9). Light-bellied Brent Goose, Oystercatcher and Herring Gull occurred on trestles in the largest numbers, while birds on trestles also represented relatively high percentages of the total count for Grey Heron, Turnstone and Hooded Crow (Table 6.10).

6.14 The percentage of Black-headed Gulls feeding was significantly higher within the trestles (paired t-test, $t = 2.3$, $p = 0.044$, $n = 12$) while the percentage of Oystercatchers feeding was significantly higher outside the trestles (paired t-test, $t = 2.3$, $p = 0.038$, $n = 17$) (Figure 6.1).

Table 6.6 – Mean counts.

Species	Bannow		Castlemaine		Ballymacoda		Dungarvan		Waterford		Poulnasherry		Number of non-zero counts
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Light-bellied Brent Goose	**228**	271	**61**	58	**78**	36	**202**	101	**114**	107	**3**	5	**24**
Shelduck	**150**	99	**76**	29	**0**	0	**0**	0	**0**	0	**26**	22	**12**
Wigeon	**24**	20	**91**	42	**319**	311	**0**	0	**0**	0	**4**	3	**18**
Teal	**0**	0	**26**	13	**1**	3	**0**	0	**0**	0	**17**	24	**7**
Mallard	**33**	54	**105**	31	**0**	0	**1**	1	**0**	0	**0**	0	**8**
Shoveler	**0**	0	**19**	30	**0**	0	**0**	0	**0**	0	**0**	0	**3**
Cormorant	**3**	2	**19**	12	**8**	6	**2**	2	**2**	1	**0**	0	**21**
Grey Heron	**1**	1	**10**	9	**6**	6	**5**	3	**2**	2	**0**	0	**22**
Oystercatcher	**110**	45	**188**	97	**137**	29	**171**	39	**138**	29	**5**	4	**29**
Ringed Plover	**1**	1	**3**	3	**8**	8	**21**	28	**3**	5	**0**	0	**16**
Golden Plover	**171**	341	**0**	0	**150**	199	**196**	170	**0**	0	**0**	0	**12**
Grey Plover	**14**	11	**12**	9	**137**	68	**24**	17	**0**	0	**16**	10	**25**
Lapwing	**323**	399	**48**	85	**55**	95	**1**	1	**1**	2	**0**	0	**13**
Knot	**0**	0	**358**	255	**102**	67	**159**	183	**0**	0	**0**	0	**14**
Sanderling	**0**	0	**23**	9	**55**	33	**2**	3	**11**	17	**0**	0	**17**
Dunlin	**810**	204	**160**	136	**772**	269	**345**	295	**0**	1	**318**	84	**26**
Black-tailed Godwit	**76**	74	**65**	44	**0**	0	**32**	59	**0**	0	**3**	3	**14**
Bar-tailed Godwit	**581**	236	**2**	4	**573**	185	**494**	232	**40**	31	**1**	2	**23**
Curlew	**197**	88	**211**	81	**65**	53	**111**	86	**66**	53	**41**	27	**29**
Greenshank	**8**	5	**14**	5	**4**	3	**5**	4	**2**	5	**2**	1	**25**
Redshank	**138**	21	**155**	88	**58**	23	**171**	86	**13**	4	**17**	13	**29**

Species	Bannow		Castlemaine		Ballymacoda		Dungarvan		Waterford		Poulnasherry		Number of non-zero counts
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Turnstone	**7**	6	**30**	17	**14**	14	**22**	12	**4**	6	**1**	1	**23**
Black-headed Gull	**331**	342	**437**	179	**42**	43	**257**	187	**311**	328	**22**	31	**29**
Common Gull	**12**	8	**69**	24	**99**	72	**164**	132	**263**	274	**16**	12	**28**
Lesser Black-backed Gull	**15**	18	**1**	2	**30**	30	**100**	158	**40**	38	**0**	0	**20**
Herring Gull	**16**	13	**81**	33	**71**	26	**74**	52	**69**	31	**2**	1	**29**
Great Black-backed Gull	**0**	0	**45**	9	**22**	19	**23**	26	**38**	28	**0**	1	**21**
Hooded Crow	**9**	3	**67**	19	**31**	12	**31**	9	**9**	6	**1**	1	**28**

Additional species (mean count < 10 at all sites): Red-breasted Merganser, Goosander, Great Northern Diver, Great Crested Grebe, Shag, Merlin, Little Egret, Snipe, Whimbrel, Mediterranean Gull, Rock Pipit, Rook and Raven..

Table 6.7 – Percentage of birds on the tideline during the main counts.

Species	Ballymacoda		Bannow		Castlemaine		Dungarvan		Poulnasherry		Waterford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Light-bellied Brent Goose	**78%**	12%			**9%**	9%	**78%**	8%			**35%**	15%
Shelduck			**66%**	23%	**7%**	4%			**13%**	13%		
Wigeon	**97%**	2%	**77%**	15%	**40%**	5%						
Teal					**15%**	7%						
Mallard					**22%**	7%						
Cormorant					**50%**	14%						
Oystercatcher	**13%**	2%	**76%**	21%	**18%**	2%	**58%**	4%			**34%**	12%
Golden Plover	**3%**	3%					**0%**	0%				
Grey Plover	**12%**	5%			**0%**	0%	**31%**	17%	**11%**	11%		
Lapwing	**0%**	0%	**75%**	25%								
Knot	**29%**	14%			**1%**	1%	**36%**	18%				
Sanderling	**33%**	17%			**50%**	29%						
Dunlin	**9%**	5%	**75%**	25%	**0%**	0%	**41%**	17%	**10%**	0%		
Black-tailed Godwit			**67%**	33%	**10%**	5%						
Bar-tailed Godwit	**32%**	10%	**80%**	20%			**92%**	5%			**68%**	23%
Curlew	**10%**	4%	**74%**	25%	**19%**	5%	**41%**	11%	**12%**	7%	**41%**	14%
Greenshank					**63%**	12%						
Redshank	**13%**	3%	**74%**	25%	**18%**	5%	**58%**	10%			**58%**	9%
Turnstone	**31%**	14%			**26%**	12%	**38%**	11%				
Black-headed Gull	**25%**	10%	**85%**	12%	**34%**	8%	**85%**	2%			**76%**	6%
Common Gull	**19%**	5%	**96%**	2%	**58%**	3%	**54%**	8%	**53%**	27%	**46%**	21%
Lesser Black-backed Gull	**4%**	2%					**1%**	1%			**99%**	1%
Herring Gull	**52%**	11%			**32%**	2%	**69%**	14%			**69%**	4%
Great Black-backed Gull	**39%**	14%			**21%**	4%	**27%**	16%			**91%**	6%
Hooded Crow	**16%**	10%			**24%**	7%	**26%**	6%				

Percentages were only calculated for species with total counts > 9. Means were only calculated for species with > 2 calculated percentages.

Table 6.8 – Mean percentages feeding.

Species	Ballymacoda		Bannow		Castlemaine		Dungarvan		Poulnasherry		Waterford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Light-bellied Brent Goose	**68%**	30%			**96%**	8%	**73%**	31%			**95%**	8%
Shelduck			**90%**	13%	**100%**	0%			**90%**	18%		
Wigeon	**88%**	10%	**100%**	0%	**82%**	9%						
Teal					**92%**	11%						
Mallard					**95%**	6%						
Cormorant					**9%**	11%						
Grey Heron	**94%**	10%										
Oystercatcher	**90%**	7%	**94%**	7%	**98%**	3%	**78%**	8%			**95%**	5%
Golden Plover	**20%**	40%					**2%**	2%				
Grey Plover	**100%**	1%			**100%**	0%	**86%**	21%	**100%**	0%		
Lapwing	**34%**	40%	**26%**	50%								
Knot	**96%**	6%			**100%**	0%						
Sanderling	**100%**	0%			**100%**	0%						
Dunlin	**77%**	27%	**99%**	1%	**100%**	0%	**89%**	20%	**100%**	1%		
Black-tailed Godwit			**89%**	19%	**100%**	0%						
Bar-tailed Godwit	**93%**	5%	**86%**	14%			**97%**	6%			**100%**	0%
Curlew	**81%**	17%	**94%**	6%	**99%**	1%	**76%**	24%	**89%**	13%	**98%**	4%
Greenshank					**100%**	0%						
Redshank	**98%**	2%	**100%**	0%	**100%**	0%	**98%**	2%			**100%**	0%
Turnstone	**100%**	0%			**93%**	14%	**98%**	4%				
Black-headed Gull	**85%**	14%	**10%**	16%	**99%**	1%	**57%**	6%			**65%**	32%
Common Gull	**72%**	29%			**96%**	4%	**39%**	21%	**67%**	58%	**67%**	43%
Lesser Black-backed Gull	**8%**	10%					**25%**	50%			**36%**	55%
Herring Gull	**52%**	17%			**96%**	5%	**38%**	27%			**74%**	24%
Great Black-backed Gull	**37%**	28%			**75%**	33%					**24%**	39%
Hooded Crow	**99%**	2%			**100%**	1%	**77%**	14%				

Percentages were only calculated for species with total counts > 10. Means were only calculated for species with > 2 calculated percentages.

Table 6.9 – Mean counts of birds on trestles.

Species	Ballymacoda		Bannow		Castlemaine		Dungarvan		Waterford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Light-bellied Brent Goose	**12.1**	22.2	**1.3**	2.5			**19.2**	24.3	**52.5**	38.7
Wigeon	**1.9**	2.4	**0.5**	1.0						
Grey Heron	**0.9**	1.5			**0.8**	1.0	**1.2**	2.2	**0.5**	0.6
Oystercatcher	**10.3**	4.0	**5.8**	3.0	**1.5**	1.3	**49.4**	11.0	**9.8**	8.4
Curlew	**0.6**	1.8	**1.5**	2.4	**2.0**	2.4	**0.4**	0.5		
Redshank	**2.3**	6.0	**0.8**	1.0	**1.0**	1.2	**0.2**	0.4		
Turnstone			**0.5**	1.0	**6.0**	7.0	**2.4**	3.0		
Black-headed Gull	**2.6**	3.4	**0.5**	0.6	**0.3**	0.5	**4.8**	3.5	**2.0**	4.0
Common Gull	**0.4**	0.7			**1.3**	1.9	**3.6**	2.7	**1.0**	1.4
Herring Gull	**7.5**	7.5	**2.0**	2.8	**1.0**	2.0	**14.2**	14.1	**28.0**	21.1
Hooded Crow	**0.4**	0.5	**4.0**	2.4	**10.3**	5.9	**10.0**	5.3	**4.8**	3.5

Additional species (all mean counts < 1): Cormorant (2 sites), Little Egret (1 site), Merlin (1 site), Dunlin (1 site), Bar-tailed Godwit (2 sites), Whimbrel (1 site), Greenshank (1 site), Great Black-backed Gull (4 sites) and Raven (1 site)

The only records of birds on trestles at Poulnasherry were 1-2 Hooded Crows on one of the main counts and three of the supplementary counts, and 1 Oystercatcher on two of the supplementary counts

Table 6.10 – Mean percentages of birds on trestles.

Species	Ballymacoda		Bannow		Castlemaine		Dungarvan		Waterford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Light-bellied Brent Goose	**15%**	28%	**1%**	1%			**8%**	10%	**43%**	38%
Wigeon	**6%**	16%	**2%**	3%						
Grey Heron	**12%**	21%			**4%**	5%	**21%**	29%	**23%**	25%
Oystercatcher	**8%**	4%	**5%**	1%	**1%**	1%	**30%**	8%	**7%**	5%
Curlew	**1%**	1%	**1%**	2%	**1%**	1%	**0%**	1%		
Redshank	**3%**	8%	**1%**	1%	**0%**	1%	**0%**	0%		
Turnstone			**7%**	13%	**17%**	14%	**9%**	13%		
Black-headed Gull	**8%**	9%	**2%**	4%	**0%**	0%	**3%**	3%	**0%**	1%
Common Gull	**0%**	1%			**2%**	2%	**4%**	4%	**1%**	1%
Herring Gull	**10%**	8%	**7%**	10%	**1%**	2%	**18%**	6%	**43%**	27%
Hooded Crow	**2%**	2%	**41%**	22%	**15%**	8%	**31%**	10%	**58%**	33%

Only species with a mean count on trestles of >1 in at least one site are shown in this table.

Assemblage analyses

6.15 *All species occur in a characteristic, limited range of habitats; and within their range, they tend to be most abundant around their particular environmental optimum. The composition of biotic communities thus changes along environmental gradients* (ter Braak and Prentice, 2004). Gradient analyses are statistical methods to extract the underlying environmental gradients that are associated with variation in species assemblages. Indirect gradient analysis extracts axes of variation in species composition that can then be related to known patterns of environmental variation. Multivariate direct gradient analysis (constrained ordination) also extracts axes of variation in species composition, but these are constrained to optimise their fit to measured environmental variables (ter Braak and Prentice, 2004).

6.16 We used gradient analyses to examine the overall response of the waterbird assemblage to intertidal oyster cultivation. We carried out exploratory analyses to identify patterns of assemblage variation using indirect gradient analyses. We then tested the hypothesis that waterbird assemblage variation is affected by the presence of oyster trestles, using multivariate direct gradient analysis.

Methods

6.17 For the analyses, we grouped the sectors in each site into three groups: 1. oyster trestle areas, 2. close controls and 3. distant controls. For sites where the OY sector contained clear areas, the bird counts within the trestles were included in the oyster trestle dataset and the bird counts outside the trestles were included in the close controls dataset. At Castlemaine Harbour, the close controls were divided into two groups to reflect the difference between the muddy habitat in group 1 and the sandy habitat in group 2. At Dungarvan Harbour, the close controls were divided into two groups to reflect the major differences in bird usage that were apparent between the upper shore sectors and the lower shore sectors. At Ballymacoda Bay, Bannow Bay and Waterford Harbour, the distant controls were divided into two groups to reflect the geographical separation of the sectors. At Poulnasherry Bay, due to the relatively small size of the study area, no distant control group was designated. The count sectors included in each group are shown in Table 6.11. A total of 21 groups were designated across all the sites, and these form the samples for the ordination analyses.

Table 6.11 – Count sectors included in the groups used in the ordination analyses.

Site	Oyster trestle group	Close controls	Distant controls
CODA	OY	CS1-CS3	Group 1: CN1-CN4 Group 2: CS4
BANN	OY^{in}	C2-C5 and OY^{out}	Group 1: C6 Group 2:C1
CAST	$OY1^{in}$, $OY2^{in}$, $OY3^{in}$, $OY4^{in}$ and $OY5^{in}$	Group 1: APP1, APP2, APP3, APP4, C3, $OY1^{out}$, $OY2^{out}$ and $OY3^{out}$ Group 2: $OY4^{out}$ and $OY5^{out}$	C1, C2 and C4
DUNG	$OY1^{in}$, $OY2^{in}$, $OY2^{in}$ and $OY4^{in}$	Group 1: $OY1^{out}$, $OY2^{out}$, $OY3^{out}$ and $OY4^{out}$ Group 2: CS1-CS4	CN1-CN4
POUL	OY	C1-C6	-
FORD[1]	$OY1^{in}$ and $OY2^{in}$	$OY1^{out}$, $OY2^{out}$, C1 and C4	C5, C6 and C7

^{in} only bird counts within trestles included in the group.
^{out} only bird counts outside trestles included in the group.
[1] Note, revisions to sector boundaries mean that sector C2 was amalgamated with sector C1, and sector C3 has been excluded from the analyses (see paragraph 4.58).

6.18 We carried out two sets of analyses: one using all species and the other using only species that predominantly feed on intertidal invertebrates. The latter group included Shelduck, Oystercatcher, Ringed Plover, Grey Plover, Knot, Sanderling, Dunlin, Black-tailed Godwit, Bar-tailed Godwit, Curlew, Greenshank, Redshank and Turnstone. Golden Plover, Lapwing, and the gull species were excluded because they feed in a range of habitats and are, therefore, not dependent on the benthic invertebrate fauna.

6.19 For all analyses, only species that occurred in three or more samples were included. We used mean numbers across all the main counts for each sample. All means were log (x+1) transformed before the analyses.

6.20 The indirect gradient analyses were carried out by non-metric multidimensional scaling analysis (NMS) using Sørensen (also known as Bray & Curtis) distance measures. The parameter set-up is shown in Table 6.12.

6.21 The direct gradient analyses were carried out using canonical correspondence analysis (CCA). We used the following categorical environmental variables: SITE, LOCATION (1 = oyster trestles and close controls; 2 = distant controls), OYSTER (1 = within trestles; 2 = outside trestles) and TLratio (tideline length/exposed intertidal area). We included TLratio to cover the possibility that differences between samples in the relative amount of tideline habitat could affect the waterbird assemblage (see paragraph 6.31).

6.22 We used cca (vegan package; Oksanen *et al.*, 2010) to carry out the analysis. We developed CCA models using stepwise selection procedures with Akaike's Information Criterion (AIC) as the primary selection criterion. The AIC measures goodness-of-fit derived from the residual (unconstrained) inertia penalized by the rank of the constraints. Because the AIC used in model building in the CCA analysis in vegan is not based on a firm theory and should only be used as an aid to model building (Oksanen, 2006) we also considered the results of permutation tests at each step, which tested the additional variance each variable explains and its significance when added to the model. The CCA analyses used biplot scaling optimising sites and the ordination diagrams use weighted average scores.

Table 6.12 - Standard parameter set-up used for NMS.

Parameter	Value used
Number of axes	2
Number of runs with real data	50
Stability criterion	0.001
Iterations to evaluate stability	10
Maximum number of iterations	250
Step down in dimensionality	Yes
Initial step length	0.20
Starting coordinates	Random
Number of runs of Monte Carlo test	249

Results

6.23 The NMS of the all species dataset produced an ordination with the oyster trestle groups separated from the other groups along axis 2 (which explained most of the variation) and with groups from each sites generally arranged together along axis 1 (Figure 6.1). Counts of most wader and gull species were significantly negatively correlated with axis 2 indicating a negative association with the oyster trestle groups. Sanderling and the gull species were significantly positively correlated with axis 1 and Mallard was significantly negatively correlated with axis 1.

6.24 The CCA analysis of the all species dataset failed to produce a model with better fit than the null model.

Table 6.13 - Non-parametric Kendall correlations between mean counts of bird species and the axis scores of the NMS ordination of the all species dataset.

	τb Axis 1	p Axis 1	τb Axis 2	p Axis 2
Light-bellied Brent Goose	.282	< 0.10	-.084	> 0.10
Shelduck	-.386	**< 0.02**	-.285	< 0.10
Wigeon	-.245	> 0.10	.044	> 0.10
Teal	-.247	> 0.10	-.306	< 0.10
Mallard	**-.386**	**< 0.02**	-.297	< 0.10
Red-breasted Merganser	-.196	> 0.10	-.183	> 0.10
Cormorant	.081	> 0.10	-.243	> 0.10
Little Egret	-.457	< 0.01	-.114	> 0.10
Grey Heron	.117	> 0.10	.107	> 0.10
Oystercatcher	.138	> 0.10	**-.329**	**< 0.05**
Ringed Plover	.260	> 0.10	**-.375**	**< 0.02**
Golden Plover	.272	< 0.10	**-.449**	**< 0.01**
Grey Plover	-.088	> 0.10	**-.363**	**< 0.02**
Lapwing	-.144	> 0.10	**-.541**	**< 0.01**
Knot	.150	> 0.10	**-.587**	**< 0.01**
Sanderling	.316	**< 0.05**	-.283	< 0.10
Dunlin	-.164	> 0.10	**-.483**	**< 0.01**
Black-tailed Godwit	-.316	< 0.10	**-.460**	**< 0.01**
Bar-tailed Godwit	.149	> 0.10	-.218	> 0.10
Curlew	-.053	> 0.10	**-.663**	**< 0.01**
Greenshank	-.175	> 0.10	-.165	> 0.10
Redshank	-.177	> 0.10	**-.463**	**< 0.01**
Turnstone	-.067	> 0.10	.160	> 0.10
Black-headed Gull	.086	> 0.10	**-.400**	**< 0.02**
Common Gull	**.419**	**< 0.01**	-.276	< 0.10
Lesser Black-backed Gull	**.381**	**< 0.02**	**-.322**	**< 0.05**
Herring Gull	**.387**	**< 0.02**	-.138	> 0.10
Great Black-backed Gull	**.384**	**< 0.02**	-.306	< 0.10
Hooded Crow	.096	> 0.10	-.135	> 0.10

6.25 The NMS and CCA of the intertidal invertebrate-feeding dataset produced ordinations with very similar arrangements of the species and samples in the ordination space. Therefore, only the CCA results are presented and discussed here.

6.26 The final CCA model included SITE and OYSTER as explanatory variables (Table 6.14). These parameters all improved the fit of the model (as measured by the AIC) and explained a significant component of additional variation (as measured by the permutation test) when added to the model.

6.27 The eigenvalues of the ordination axes and the species-environment correlations are high (Table 6.14) and, overall 61% of the assemblage variation is explained by the constrained axes.

6.28 The CCA triplot (Figure 6.3) shows two main directions of assemblage variation: along the OYSTER vector with the oyster trestle groups clearly separated from the other groups (apart from Bannow Bay-D2); and, orthogonal to the first direction, a separation between sites, with Bannow Bay, Castlemaine Harbour and Poulnasherry Bay separated from Ballymacoda Bay, Dungarvan Harbour and Waterford Harbour.

6.29 In order to more clearly examine the arrangement of species along the OYSTER vector, we repeated the CCA with SITE as a covariable. Axis 1, which represents the OYSTER vector, explains 14% of the variation. The ordering of species along the OYSTER vector is shown in Figure 6.4. In this ordination Turnstone, and to a lesser extent Oystercatcher, Redshank and Greenshank are positively associated with the oyster trestle groups while Shelduck, Ringed Plover, Grey Plover, Knot, Sanderling, Dunlin and Black-tailed Godwit are negatively associated with the oyster trestle groups. In this ordination, the displacement of species along axis 2 is an indication of the amount of variation that is not explained by the SITE and OYSTER variables.

Table 6.14 – Summary of the final CCA model.

	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Eigenvalues	0.107	0.104	0.048	0.026	0.016	0.007
Variance explained	21%	21%	9.4%	5.2%	3.1%	1.4%
Species-environment correlations	0.91	0.91	0.88	0.69	0.72	0.68

Species analyses

6.30 We tested the null hypothesis that bird distribution within our study areas was not affected by the presence of oyster trestles, so that the observed occurrence of birds within areas of oyster trestles was not significantly different from that predicted by the percentage of the available habitat occupied by the oyster trestles.

6.31 Because many waterbirds follow the tideline, and the tideline may provide particularly favourable habitat, it is necessary to consider the distribution of tideline habitat, as well as the total area of intertidal habitat in this type of analysis. Therefore, we calculated the expected number of birds in areas of oyster trestles using the following formula:

Expected number = (total number in intertidal away from tideline * proportion of intertidal habitat area within oyster trestles) + (total number on tideline * proportion of tideline within oyster trestles)

6.32 We only included counts with totals of ten or more birds in these analyses and we have only included species with at least three qualifying counts in at least two sites.

6.33 For each species, we carried out two analyses: one using all the sectors and the other using the oyster trestle sectors and the control sectors close to them. For each site, the latter group of sectors was based on the oyster trestle and close control groups in Table 6.11. For Castlemaine Harbour and Dungarvan Harbour, we examined the sector distribution of each species and only included the Group 2 close controls when there was no obvious difference in the occurrence of the species between the Group 1 and Group 2 close controls.

6.34 We then compared the observed number with the expected number. We used scattergraphs to compare the data visually and to identify any differences between sites in the relationship between observed and expected numbers.

6.35 For species, with sufficient data we also carried out separate analyses of birds on the tideline and/or in the intertidal away from the tideline, and birds feeding and/or roosting. However, we have only presented the results of these analyses where they differ from the overall analyses.

6.36 We had intended to use the representation rate index of Godet *et al*. (2010) to analyse patterns of association with oyster trestle blocks. However, we had difficulties in the interpretation of the index values. The index has a minimum value of -1 for species with negative associations, but a variable maximum value, which may be orders of magnitude higher than the minimum value, for species with positive associations. Furthermore, the index is very sensitive to differences of a few birds when small numbers are present.

6.37 We have not carried out statistical analysis of this data. Any such analysis would require a complex mixed-model approach because the potential differences between sites would need to be accounted for and because the design is unbalanced. The small number of replicates per site means that the power of the analysis to detect site differences would be low. We consider that the patterns in the data are clear from the graphical presentations.

6.38 The following species accounts describe the general pattern of the species occurrence at our study sites and then analyse the distribution of the species in relation to the presence of oyster trestle blocks. The distribution of the count sectors at each site are shown in Figure 4.7-Figure 4.13. The key patterns that emerge from the individual species analyses are summarised in the Discussion (paragraphs 8.12-8.32).

Light-bellied Brent Goose

6.39 Light-bellied Brent Goose occurred at all the sites, with mean counts of 61-228 birds, apart from Poulnasherry Bay where the mean count was only three.

6.40 At Ballymacoda Bay and Dungarvan Harbour, most birds were on the tideline, while at Castlemaine Harbour and Waterford Harbour most birds were in intertidal habitat. At these sites, 68% or more of the birds were feeding.

6.41 At Ballymacoda Bay, birds mainly occurred in the outer sectors (CN2-CN4, CS1, CS2 and OY).

6.42 At Bannow Bay, the species only occurred on two of the four counts and its distribution was restricted to the middle sectors (C2-C5, OY1 and OY2).

6.43 At Castlemaine Harbour, birds occurred in the inner sectors (i.e., excluding APP1, C1, C2 and C4).

6.44 At Dungarvan Harbour, birds mainly occurred in the eastern sectors on the northern side of the bay (CN1 and CN2), as well as CN5, and the lower sectors on the southern side of the bay (OY1-OY4).

6.45 At Waterford Harbour, birds only occurred in three sectors (C5, OY1 and OY2).

Analysis

6.46 The comparisons of observed and predicted numbers show a wide scatter of data without consistent trends across sites (Figure 6.5)

6.47 At Dungarvan Harbour and Waterford Harbour, observed numbers within the oyster trestle blocks were broadly in line with predicted numbers. At Bannow Bay and in the majority of counts at Ballymacoda Bay, observed numbers within the trestle blocks were lower than the predicted numbers. However, on the two counts at Ballymacoda Bay on the third count day, observed numbers were higher than predicted numbers. On this count day, the tideline remained in the upper section of the trestles throughout the low tide period and there were no husbandry activities in the oyster trestles.

Shelduck

6.48 Shelduck occurred at three sites with mean counts of 150 at Bannow Bay, 76 at Castlemaine Harbour and 26 at Poulnasherry Bay.

6.49 At Bannow Bay, around two-thirds occurred in the tideline, while at Castlemaine Harbour and Poulnasherry Bay most birds occurred on intertidal habitat away from the tideline. At all three sites, 90% or more of the birds were feeding.

6.50 At Bannow Bay most Shelduck occurred in sector C6. At Castlemaine Harbour and Poulnasherry Bay, Shelduck occurred in various sectors scattered throughout the study areas.

Analysis

6.51 Shelduck were only recorded within oyster trestle blocks at Bannow Bay, where they were recorded on two counts (2 and 4 birds, respectively).

6.52 At Bannow Bay, most Shelduck occurred in the large northernmost sector (C6) well away from the trestle blocks. When this sector is excluded, in the close sectors analysis, predicted numbers were 1-8, compared to recorded numbers of 0-4. At Castlemaine Harbour and Poulnasherry Bay, predicted numbers in both analyses were also very low (0-1 at Castlemaine Harbour and 1-7 at Poulnasherry Bay).

Wigeon

6.53 Wigeon occurred at four of the sites surveyed, with mean counts of 319 at Ballymacoda Bay, 91 at Castlemaine Harbour, 24 at Bannow Bay and 4 at Poulnasherry Bay.

6.54 At Ballymacoda Bay and Bannow Bay most birds were on the tideline while at Castlemaine Harbour most birds were in intertidal habitat. At these sites, 82% or more of the birds were feeding.

6.55 At Ballymacoda Bay, birds mainly occurred in the sectors that border the Womanagh River tidal channel (CN1 and CN2 and CS2-CS4). As 88% of birds occurred on the tideline, this distribution pattern shows an association with the tidal river channel; this is consistent with this species known behaviour.

6.56 At Bannow Bay, the species only occurred on three of the four counts and its distribution was restricted to the middle sectors (C2-C5, OY1 and OY2).

6.57 At Castlemaine Harbour, birds occurred throughout the study area, apart from the outermost sandbank (C4).

Analysis

6.58 At Ballymacoda Bay, observed numbers within the oyster trestle blocks were consistently much lower than the predicted numbers, based on the overall distribution of habitat (Figure 6.6). However, Wigeon showed a strong association with the tidal channel, and the trestle blocks do not adjoin the tidal channel. Therefore, Wigeon would not be expected to show a positive association with sector OY, regardless of the presence or absence of oyster trestles.

6.59 At Bannow Bay and Castlemaine Harbour observed and predicted numbers were both very low, apart from one count at Bannow Bay when 29 Wigeon were recorded within the trestle blocks on the tideline.

Oystercatcher

6.60 Oystercatcher occurred at all the sites, with mean counts of 110-188 birds, apart from Poulnasherry Bay where the mean count was only five.

6.61 At Bannow Bay most birds were on the tideline, while at Ballymacoda Bay, Castlemaine Harbour and Waterford Harbour most birds were in intertidal habitat. At all sites, 78% or more of the birds were feeding.

6.62 At Bannow Bay, birds occurred throughout the site, but with very low numbers in the two southernmost sectors (C1 and C2). At Poulnasherry Bay, birds only occurred in sectors C1, C6 and OY. At the other sites, birds occurred in most sectors throughout the study areas.

Analysis

6.63 Across all sites, observed numbers within the oyster trestle blocks were broadly in line with the predicted numbers (Figure 6.7).

6.64 At Dungarvan Harbour and Waterford Harbour (apart from one count in the close sectors analysis), observed numbers within the oyster trestle blocks were higher than the predicted numbers.

Grey Plover

6.65 Grey Plover occurred at all the sites, except Waterford Harbour, with a mean count of 137 at Ballymacoda Bay and 12-24 at the other sites.

6.66 Across all sites, birds mainly occurred in intertidal habitat away from the tideline and 86% or more of the birds were feeding.

6.67 At Dungarvan Harbour, birds only occurred on the southern side of the bay, apart from one bird in CN4 on one count. At Poulnasherry Bay, birds only occurred in sectors C4 and C6. In the other sites, Grey Plovers were either very scarce or distributed fairly evenly throughout the study areas.

Analysis

6.68 Across all sites, observed numbers within the oyster trestle blocks were lower than the predicted numbers (Figure 6.8).

6.69 Although Grey Plover rarely occurred within the trestle blocks, at most sites the difference between observed and predicted numbers was low because of the low overall numbers of Grey Plover. However, in the close sectors analysis five counts (four at Ballymacoda Bay and one at Dungarvan Harbour) had predicted numbers of 18-40 and observed numbers of 0-7.

Lapwing

6.70 Lapwing occurred at five sites, with mean counts of 323 at Bannow Bay, 48-55 at Ballymacoda Bay and Castlemaine Harbour and 1 at Dungarvan Harbour and Waterford Harbour.

6.71 At Bannow Bay, most birds were on the tideline, while at Ballymacoda Bay all birds were in intertidal habitat away from the tideline. At both these sites around two-thirds of the birds were roosting.

6.72 At Bannow Bay, Lapwing occurred in sectors C3, C4 and C6. At Ballymacoda Bay, Lapwing only occurred in sector CS4.

Analysis

6.73 Lapwings were not recorded within oyster trestle blocks at any of the sites.

6.74 At Ballymacoda Bay, Lapwing only occurred in the upper shore zone. Therefore, the absence of Lapwing from the trestle blocks in the lower shore does not indicate avoidance of oyster trestles at this site.

6.75 At Bannow Bay, predicted numbers within trestle blocks were 1, 13, 32 and 109 in the all sectors analysis and 20 and 49 in the two qualifying counts in the close sectors analysis. At Castlemaine Harbour, predicted numbers within oyster trestles were 0 in the two qualifying counts in the all sectors analysis and 0 in both qualifying counts in the close sectors analysis.

Knot

6.76 Knot occurred at Ballymacoda Bay, Castlemaine Harbour and Dungarvan Harbour with mean counts of 102-358 birds.

6.77 At all these sites most birds occurred in intertidal habitat away from the tideline and 96% or more of the birds were feeding.

6.78 At Castlemaine Harbour, Knot mainly occurred on the large outer sandbanks (sectors C1 and C2). At Ballymacoda Bay and Dungarvan Harbour, Knot occurred in various sectors scattered throughout the study areas.

Analysis

6.79 Knot was not recorded within oyster trestle blocks at any of the sites.

6.80 At Ballymacoda Bay, predicted numbers within trestle blocks ranged from 2-60 (mean = 24, n =8) in the all sectors analysis and 2-43 (mean = 15, n = 5) in the close sectors analysis. In the all sectors analysis at Castlemaine Harbour, predicted numbers were 0-2, while at Dungarvan Harbour predicted numbers were 20-58, in three qualifying counts at each of these sites. At Dungarvan Harbour, predicted numbers were 13 in the one qualifying count in the close sectors analysis.

6.81 The unidentified birds in sector CN4 at Dungarvan Harbour (see paragraph 6.6), if Knot, would not significantly alter the relationship between observed and expected numbers

Dunlin

6.82 Dunlin occurred at all the sites, with mean counts of 160-810 birds, apart from Waterford Harbour where the mean count was less than one.

6.83 At Bannow Bay, most birds were on the tideline while at Ballymacoda Bay and Poulnasherry Bay most birds were in intertidal habitat away from the tideline. Across all sites, 77% or more of the birds were feeding.

6.84 At all the sites, birds occurred throughout the study areas.

Analysis

6.85 Across all sites, observed numbers within the oyster trestle blocks were lower than the predicted numbers, apart from single counts at Dungarvan Harbour and Waterford Harbour (Figure 6.9).

6.86 At Bannow Bay, Ballymacoda Bay and Castlemaine Harbour, no Dunlin occurred within the trestle blocks (apart from three birds on one count at Ballymacoda Bay), despite predicted numbers of up to 117 at Bannow Bay and 359 at Ballymacoda Bay.

6.87 At Dungarvan Harbour, 10-40 Dunlin occurred within the trestle blocks. The unidentified birds in sector CN4 (see paragraph 6.6), if Dunlin, would not significantly alter the relationship between observed and expected numbers.

6.88 The mean densities outside and within trestle blocks are shown in Table 6.15.

Table 6.15 - Mean densities of Dunlin outside and within oyster trestle blocks

Site	Analysis	Tideline (birds/km)				Intertidal (birds/km^2)			
		Outside		Within		Outside		Within	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ballymacoda Bay	All sectors	**45.5**	66.3	**0.9**	2.0	**267**	71.4	**0.0**	0.0
	Close sectors	**223**	351	**0.9**	2.0	**485**	207	**0.0**	0.0
Bannow Bay	All sectors	**60.4**	17.1	**0.0**	0.0				
	Close sectors	**21.8**	18.3	**0.0**	0.0				
Castlemaine Harbour	All sectors					**11.3**	7.5	**0.0**	0.0
	Close sectors					**21.1**	13.3	**0.0**	0.0
Dungarvan Harbour	All sectors	**16.3**	24.3	**8.2**	9.6	**42.8**	55.9	**5.9**	4.7
	Close sectors					**45.6**	73.3	**5.9**	4.7
Poulnasherry Bay	n/a					**563**	242	**226**	423

Black-tailed Godwit

6.89 Black-tailed Godwit occurred at four sites with mean counts of 32-76 at Bannow Bay, Castlemaine Harbour and Dungarvan Harbour and three at Poulnasherry Bay.

6.90 At Bannow Bay, most birds were on the tideline while at Castlemaine Harbour most birds were in intertidal habitat away from the tideline. At these sites, 89% or more of the birds were feeding.

6.91 On two of the three counts when Black-tailed Godwit were recorded at Bannow Bay, most birds were in sector C6. At Castlemaine Harbour, Black-tailed Godwit occurred in scattered sectors across most of the study area. At Dungarvan Harbour, Black-tailed Godwit only occurred in sectors on the northern side of the bay.

Analysis

6.92 At the three main sites, apart from one observations of a single bird at Castlemaine Harbour, Black-tailed Godwit were not recorded within oyster trestle blocks. However, at Poulnasherry Bay, of the 13 birds recorded across all four counts, seven were within the trestle blocks.

6.93 In the all sectors analysis, predicted numbers within the trestle blocks were 11, 15 and 3 on the three qualifying counts at Bannow Bay, 0-1 in the three qualifying counts at Castlemaine Harbour and 1 and 18 on the two qualifying counts at Dungarvan Harbour. In the close sectors analysis, predicted numbers within the trestle blocks were 1, 8 and 3 on the three qualifying counts at Bannow Bay and 0-1 in the three qualifying counts at Castlemaine Harbour. There were no qualifying counts in the close sectors analysis at Dungarvan Harbour.

Bar-tailed Godwit

6.94 Bar-tailed Godwits occurred at all the sites, with mean counts of 500-600 at Bannow Bay, Ballymacoda Bay and Dungarvan Harbour, 40 at Waterford Harbour and 1-2 at Castlemaine Harbour and Poulnasherry Bay.

6.95 At Bannow Bay and Dungarvan Harbour, most birds were on the tideline, while at Ballymacoda Bay most birds were in intertidal habitat. At all sites, 86% or more of the birds were feeding

6.96 At Bannow Bay, birds occurred throughout the study area, but showed a strong association with sector C6. Excluding C6, birds on the tideline showed a positive association with sectors C3 and C4 and the clear parts of sectors OY1 and OY2.

6.97 At Ballymacoda Bay, birds occurred throughout the study area. The mean count on the northern side of the bay (389, s.d. 153) was around twice as high as the mean count on the southern side of the bay (185, s.d., 115). In sectors CN2-CN4, most birds were on clear sand (mean 92%, s.d. 14%). Birds on the tideline showed a strong association with sector CN4, and a negative association with sector OY. Birds on the intertidal showed strong associations with CN3 and CS2 and negative associations with CN2, CS4 and OY.

6.98 At Dungarvan Harbour, birds occurred through most of the study area, but were absent from the upper shore sectors (CS1-CS3) on the southern side of the bay, as well as CS4 and CN3. On four of the five counts, much larger numbers occurred on the northern side of the bay. Birds on the tideline showed positive associations with sectors CN1, CN2 and CN4 and negative associations with sectorsOY1-OY4. Birds only occurred in intertidal habitat during the first two counts, with 90% or more occurring in the northern sectors.

6.99 At Waterford Harbour, birds only occurred in sectors C4 and C5.

Analysis

6.100 Across all sites, observed numbers within the trestles were lower than the predicted numbers, apart from single counts at Dungarvan Harbour and Bannow Bay (the latter during the close sector analysis only) (Figure 6.10).

6.101 In the all sectors analysis, the observed numbers were much lower than the predicted numbers in most counts across all the sites.

6.102 In the close sectors analysis, observed numbers were generally only slightly lower than predicted numbers in Bannow Bay and Dungarvan Harbour, but remained much lower than predicted numbers in most of the counts at Ballymacoda Bay.

6.103 The mean densities of Bar-tailed Godwits in tideline habitat were 4.5-8.6 times higher outside compared to within oyster trestle blocks at Ballymacoda Bay and Bannow Bay (Table 6.16). At Dungarvan harbour, the mean density was 3.75 times higher outside compared to within oyster trestle blocks in the all sectors analysis. However, on one of the five counts the main Bar-tailed Godwit flock was absent. When this count is excluded, the mean density was just over five times higher. In the close sectors analysis, the mean density was 1.85 times higher outside compared to within oyster trestle blocks.

Table 6.16 – Mean densities of Bar-tailed Godwit outside and within oyster trestle blocks.

Site	Analysis	Tideline (birds/km)				Intertidal (birds/ha)			
		Outside		Within		Outside		Within	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ballymacoda Bay	All sectors	**66.2**	38.0	**10.1**	14.6	**1.68**	1.01	**0.08**	0.25
	Close sectors	**69.7**	44.0	**10.1**	14.6	**2.15**	1.85	**0.08**	0.25
Bannow Bay	All sectors	**38.9**	27.1	**4.5**	4.0	**0.33**	0.65	**0.07**	0.15
	Close sectors	**20.5**	16.9	**4.5**	4.0	**0.08**	0.15	**0.07**	0.15
Dungarvan Harbour	All sectors	**56.3**	25.7	**15.0**	7.7	**0.04**	0.05	**0.05**	0.01
	All sectors	**67.2**	9.4	**13.0**	7.2				
	Close sectors	**27.8**	12.3	**15.0**	7.7	**0.03**	0.05	**0.05**	0.01
Waterford Harbour	All sectors	**5.8**	5.2	**0.0**	0.0	**0.10**	0.11	**0.00**	0.00
	Close sectors	**9.8**	9.5	**0.0**	0.0	**0.20**	0.23	**0.00**	0.00

Curlew

6.104 Curlew occurred at all the sites, with mean counts of 41-211 birds.

6.105 At Bannow Bay, most birds were on the tideline while at Ballymacoda Bay, Castlemaine Harbour and Poulnasherry Bay most birds were in intertidal habitat away from the tideline. Across all sites, 76% or more of the birds were feeding.

6.106 Birds generally occurred throughout each the study area site, without consistent preferences for particular areas.

Analysis

6.107 The comparisons of observed and predicted numbers show a wide scatter of data without consistent trends across sites (Figure 6.11).

6.108 At Castlemaine Harbour, observed numbers were consistently higher than predicted numbers, but both observed and predicted numbers were low.

6.109 At Ballymacoda Bay and Waterford Harbour, very few Curlew were observed within the oyster trestle blocks and observed numbers were consistently lower than predicted numbers.

6.110 At Dungarvan Harbour, the relationship between observed and predicted numbers varied between counts.

6.111 At Poulnasherry Bay, observed and predicted numbers were more or less the same.

Redshank

6.112 Redshank occurred at all the sites, with mean counts of 13-38 birds.

6.113 At Bannow Bay, most birds were on the tideline while at Ballymacoda Bay and Castlemaine Harbour most birds were in intertidal habitat away from the tideline. Across all sites, 98% or more of the birds were feeding.

6.114 At Ballymacoda Bay, Redshank mainly occurred in the sectors on the southern side of the bay (CS1-CS4 and OY). At Bannow Bay, Redshank showed a strong association with sector C6. At Dungarvan Harbour, Redshank mainly occurred in the lower sectors (OY1-OY4) on the southern side of the bay.

Analysis

6.115 The overall trend across all sites was for observed numbers within the trestles to be broadly in line with the predicted numbers (Figure 6.12).

6.116 At Dungarvan Harbour, observed numbers were substantially higher than predicted numbers on four of the five counts in the all sectors analysis, but the difference was much less marked in the close sectors analysis. This reflected the fact that the Redshank distribution in the study area at Dungarvan Harbour was concentrated in the sectors containing the oyster trestle blocks. The unidentified birds in sector CN4 (see paragraph 6.6), if Redshank, would not significantly alter the relationship between observed and expected numbers: they would increase the expected numbers from 31 to 34 and 44 to 50 on days when the observed numbers were 115 and 128, respectively.

6.117 At Bannow Bay, observed numbers were lower than predicted numbers on all four counts, although the difference was more marked in the all sectors analysis compared to the close sectors analysis.

Turnstone

6.118 Turnstone occurred at all the sites, with mean counts of 14-30 at Ballymacoda Bay, Castlemaine Harbour and Dungarvan Harbour and 1-7 at the other sites.

6.119 Across all the sites most birds occurred in intertidal habitat away from the tideline and 93% or more of the birds were feeding.

6.120 However, birds on the oyster trestles could be difficult to detect, particularly when they were roosting, so both the total counts and the proportion of birds roosting may have been under-estimated.

6.121 At Castlemaine Harbour, Turnstone mainly occurred in the sectors along the upper shore. At Dungarvan Harbour, Turnstone mainly occurred in sector CN2, OY3 and OY4. In the other sites, Turnstone were either very scarce or distributed fairly evenly throughout the study areas.

Analysis

6.122 The overall trend across all sites was for observed numbers within the trestles to be considerably larger than the predicted numbers (Figure 6.13).

6.123 Ballymacoda Bay was an exception to this trend, and Turnstone were never recorded within the trestles at Ballymacoda Bay. However, predicted numbers at Ballymacoda Bay were very low.

Black-headed Gull

6.124 Black-headed Gull occurred at all the sites, with mean counts 22-42 at Ballymacoda Bay and Poulnasherry Bay and 257-437 at the other four sites.

6.125 At Bannow Bay, Dungarvan Harbour and Waterford Harbour, most birds were on the tideline while at Ballymacoda Bay and Castlemaine Harbour most birds were in intertidal habitat away from the tideline. At Ballymacoda Bay and Castlemaine Harbour, 85% or more of the birds were feeding, while at Bannow Bay only 10% of the birds were feeding.

6.126 At Ballymacoda Bay, Black-headed Gull mainly occurred in the sectors on the southern side of the bay (CS1-CS4 and OY). At Bannow Bay, Black-headed Gull showed a strong association with sector C6. At Dungarvan Harbour, Black-headed Gull mainly occurred in the sectors along the outer edge of the bay (CN1 and OY1-OY4). In the other sites, Black-headed Gull were distributed fairly evenly throughout the study areas.

Analysis

6.127 The comparisons of observed and predicted numbers show a wide scatter of data without consistent trends across all the sites (Figure 6.14).

6.128 On counts with predicted numbers of up to around 50, observed numbers showed an equal spread around the 1:1 line. Counts with higher predicted numbers, always had observed numbers much lower than the predicted numbers.

Common Gull

6.129 Common Gull occurred at all the sites, with mean counts 12-16 at Bannow Bay and Poulnasherry Bay and 69-263 at the other four sites.

6.130 At Bannow Bay, most birds were on the tideline while at Ballymacoda Bay most birds were in intertidal habitat away from the tideline. At Castlemaine Harbour, 96% of the birds were feeding, at Dungarvan Harbour only 39% of the birds were feeding, while at the other sites 67-72% of the birds were feeding.

6.131 At Dungarvan Harbour, Common Gull mainly occurred in sector CN1 and the sectors on the southern side of the bay. At Waterford Harbour, large counts occurred in sector C4 on two of the four count days. In the other sites, Common Gull were distributed fairly evenly throughout the study areas.

Analysis

6.132 Across all the sites, observed numbers within the oyster trestle blocks were broadly in line with the predicted numbers up to predicted numbers of around 40. When predicted numbers were higher, observed numbers were much lower than the predicted numbers (Figure 6.15).

Lesser Black-backed Gull

6.133 Lesser Black-backed Gull occurred at five of the sites with mean counts of 100 at Dungarvan Harbour, 15-40 at Ballymacoda Bay, Bannow Bay and Waterford Harbour and 1 at Castlemaine Harbour.

6.134 At Waterford Harbour nearly all birds were on the tideline while at Ballymacoda Bay and Dungarvan Harbour nearly all birds were in intertidal habitat away from the tideline. At all three of these sites most birds were roosting.

6.135 At Ballymacoda Bay, most birds occurred in sector CS4. At Dungarvan Harbour most birds occurred in sectors on the southern side of the bay. At Waterford Harbour, large flocks occurred in sector C7 on two counts, with very low overall numbers on the other counts.

Analysis

6.136 Lesser Black-backed Gull only occurred within oyster trestle blocks on two counts (3 birds on one count at Bannow Bay and 4 birds on one count at Waterford Harbour). However across the 12 qualifying counts in the all sectors analysis predicted numbers were usually low (less than 10). The exceptions were one count at Dungarvan Harbour, with predicted numbers of 52 and two counts at Waterford Harbour, with predicted numbers of 20 and 24. These were all counts where large roosting flocks occurred.

Herring Gull

6.137 Herring Gull occurred at all the sites, with mean counts 2-16 at Bannow Bay and Poulnasherry Bay and 69-81 at the other four sites.

6.138 At Dungarvan Harbour and Waterford Harbour, most birds were on the tideline while at Castlemaine Harbour most birds were in intertidal habitat away from the tideline. At Castlemaine Harbour and Waterford Harbour, 74% or more of the birds were feeding, while at Dungarvan Harbour only 38% of the birds were feeding.

6.139 At Dungarvan Harbour, Herring Gull mainly occurred in sectors OY1-OY4. At Waterford Harbour, Herring Gull mainly occurred in sectors OY1 and OY2. In the other sites, Herring Gull were distributed fairly evenly throughout the study areas.

Analysis

6.140 Across all sites observed numbers were closely correlated with predicted numbers and evenly distributed around the 1:1 line (Figure 6.16).

Great Black-backed Gull

6.141 Great Black-backed Gull occurred at all the sites except Bannow Bay with mean counts of less than one at Poulnasherry Bay and 22-45 at the other sites.

6.142 At Waterford Harbour, most birds occurred in the tideline while at Ballymacoda Bay, Castlemaine Harbour and Dungarvan Harbour most birds occurred in intertidal habitat away from the tideline. At Castlemaine Harbour, 75% of the birds were feeding while at Ballymacoda Bay and Waterford Harbour most birds were roosting.

6.143 At Ballymacoda Bay, birds were generally concentrated in sectors CS2-CS4. At the other sites, birds generally occurred in scattered sectors across most of the study areas.

Analysis

6.144 Observed numbers were generally lower than predicted numbers; apart from at Castlemaine Harbour and in, the close sectors analysis, two of the counts at Ballymacoda Bay (Figure 6.17). However predicted numbers were usually low (less than 10). The high predicted value in the all sectors analysis for one count at Waterford Harbour was due to a roosting flock of 73 in sector C7. The high predicted value in the close sectors analysis for one count at Dungarvan Harbour was due to a roosting flock of 53 in sectors CS3 and CS4.

Additional counts

6.145 Partial additional second count series were carried out at Dungarvan Harbour and Poulnasherry Bay, and partial additional third count series were carried out at

Disturbance

6.146 Oyster husbandry activity was observed during all the counts at Dungarvan Harbour and Waterford Harbour, on three of the four counts at Castlemaine Harbour and Poulnasherry Bay, on three counts at Bannow bay (disturbance information was not recorded on one count) and on two out of three counts at Ballymacoda Bay (disturbance information was not recorded on one count) (Table 6.17).

6.147 Minor impacts, involving birds being disturbed by husbandry activity but not being displaced from the count sector, were noted on one count at Ballymacoda Bay, one count at Castlemaine Harbour, five counts at Dungarvan Harbour, two counts at Poulnasherry Bay, and two counts at Waterford Harbour. A moderate impact, involving a small flock being disturbed by husbandry activity and being displaced from the count sector, was recorded one count at Dungarvan Harbour. A high impact, involving disturbance of all birds within a 200 m radius by a dog accompanying workers, was recorded at Castlemaine Harbour. However, it should be noted that, as recording disturbance impacts was not the primary aim of this study, other disturbance impacts on the count days are likely to be missed. In particular, the counter at Castlemaine Harbour noted that, because of the size of the study area, entire disturbance events may have been missed.

6.148 Other potentially disturbing activities recorded during the counts are summarised in Table 6.18.

Table 6.17 – Oyster husbandry activity and disturbance impacts during the extensive study.

Site	Count day	No. of Vehicles[1]	No. of people[2]	Impact[3]	Description of activity and impacts
Ballymacoda Bay	1	1 tractor	2	Minor	One tractor and two men arrived to work on trestles. The tractor drove through CS1 and went into OY. They remained within OY in a very limited area, with the men never going more than about 20 m of the tractor. Their arrival was not closely observed: a few waders were in the air at OY, but probably redistributed within the sector, rather than leaving it. During the counts no birds responded to the men either within OY or in other sectors. When the tractor left, no birds within the sector responded, but there were very few birds there anyway. The same route was followed by the tractor out of the site. PB and WN within CS1 responded by swimming out a little from the tideline. Wading birds within CS1 continued feeding.
	2	NR	NR	None	Shellfish workers already in situ at the start of the count and the last of them left during the period 13:00-13:30. No birds moved between sectors as they left. Work took place over most of the trestle area.
	3	0	0	None	No workers were at trestles (the tide did not recede enough) and no planes, helicopters or other activity occurred.
	4	NO INFORMATION RECORDED			
Bannow Bay	1	2 tractors	NR	NR	
	2	NO INFORMATION RECORDED			
	3	1 tractor	2	None	No visible disturbance
	4	2 tractors	2	None	No birds in vicinity of workers
Castlemaine Harbour	1	1 boat	3	Minor	In OY5 and seen from VP1 so very distant. Some slight disturbance with some OC and CU flying away from their general area.
	1	1 boat	2	High	With a dog. 1 man walked boat along channel. Dog was let out onto sand and spent next 40 minutes chasing every bird out of c. 200 m radius - CU, OC and gulls.
	1	1 boat	2	None	Motored up channel in OY 4 and OY5. Tide well in so boat not that close to shoreline and no shorebirds disturbed. Boat activity actually attracted c.10 BH.
	1	1 tractor		None	Tractor arrived on eastern shoreline of Cromane opposite OY3 and man started loading boxes from a boat. No birds disturbed (though none were on shoreline when tractor arrived).
	2	2 boats	2	No	
	3	0	0	No	No disturbance events during any counts. No boats or men venturing out in wind and rain.
	4	1 boat	2	No	Active before count took place. Returned to Cromane.
Dungarvan	1	7 tractors	29	Minor	Working on trestles in sectors OY2-OY4, with a lot of movement between different areas of the trestle blocks.

Site	Count day	No. of Vehicles[1]	No. of people[2]	Impact[3]	Description of activity and impacts
Harbour	2	9 tractors	29	Minor	Working on trestles in sectors OY2-OY4, with a lot of movement between different areas of the trestle blocks. One tractor flushed a few birds as it drove along the tideline within OY3, but these re-settled within the same area.
	3	9 tractors	27	Minor	Working on trestles in sectors OY2-OY4, with a lot of movement between different areas of the trestle blocks. One tractor flushed 7 OC and 3 RK while moving within sector OY3. Birds re-settled within the sector.
	4	12 tractors	31	Moderate	Working on trestles in sectors OY2-OY4, with a lot of movement between different areas of the trestle blocks. One tractor flushed 12 OC and 3 RK from the tideline in OY2 while moving trestles; these birds flew off north. Another tractor flushed 1 RK while arriving at trestles in OY2.
	5	11 tractors	42	Minor	Working on trestles in sectors OY2-OY4, with a lot of movement between different areas of the trestle blocks. One tractors flushed 5RK and 1 TT while moving within OY3; birds resettled nearby. Another tractor flushed a mixed flock of waders feeding on the intertidal outside the trestle blocks in OY1 while travelling from slip at Moat; birds resettled nearby.
Poulnasherry Bay	1	1 car	1	Minor	Working on oyster trestles at most north-western tip of OY. Minor disturbance close to where he worked.
	2	1 tractor	2	Minor	Drove along causeway straight down to southern end of trestles, and back to the causeway around 30 minutes later.
	3	1 tractor	1	None	Drove straight over from the eastern side of bay without stopping to work in study area.
	4	0	0	None	No oyster husbandry activity observed.
Waterford Harbour	1	4 tractors	11	None	Birds feeding happily within a short range of workers. At end of count noted mixed flock of gulls being fed scraps by one of the workers.
	2	4 tractors	12	Minor	Groups of men working on oyster trestles. Occasional movement of waders but only short distances. Birds readily accept presence of workers.
	3	4 tractors	10	None	No birds in immediate area except for some BH and CM following tractors
	4	5 tractors	14	Minor	Men working on trestles keeping birds away from immediate area.

NR = not recorded.
[1] Figures for Dungarvan Harbour are the maximum number present at any one time during the observation period.
[2] Figures for Dungarvan Harbour are approximate.
[3] None = None observed.

Table 6.18 – Number of count days on which non-oyster husbandry activities and impacts were observed during the extensive study.

Impact		Ballymacoda Bay	Castemaine Harbour	Dungarvan Harbour	Poulnasherry bay	Waterford Harbour
Bait digging	Recorded	3		1		1
	Impacts	1 minor				
Shellfish gatherers	Recorded			5	4	
	Impacts			2 minor	1 minor	
Walkers	Recorded	1		2		1
	Impacts			1		
Walkers with dogs	Recorded	1		2		
	Impact			1 moderate		
Dogs	Recorded			4		
	Impacts			2 major		
Horse riders	Recorded			5		1
	Impacts			1 minor 2 moderate		
Pony cart	Recorded			1		
Helicopter	Recorded	1				
	Impact	1 major				
Birds of prey	Recorded	1	1			
	Impacts	1 minor	1 minor			

No non-oyster husbandry activities were recorded at Bannow Bay.
Activities on the shoreline above the intertidal are not included unless they caused disturbance to birds.

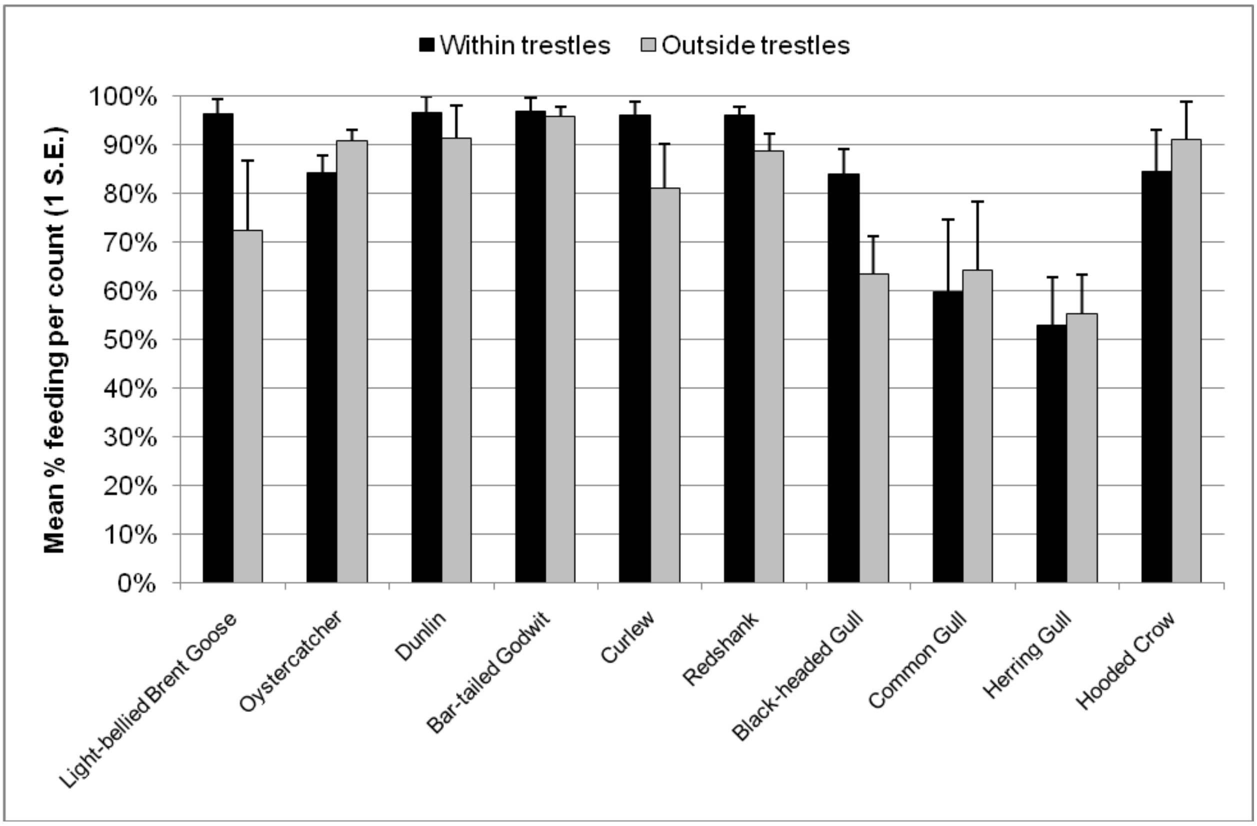


Figure 6.1 – Comparison of mean percentages feeding within and outside trestles, using data from counts across all sites with > 9 birds within and outside trestles.

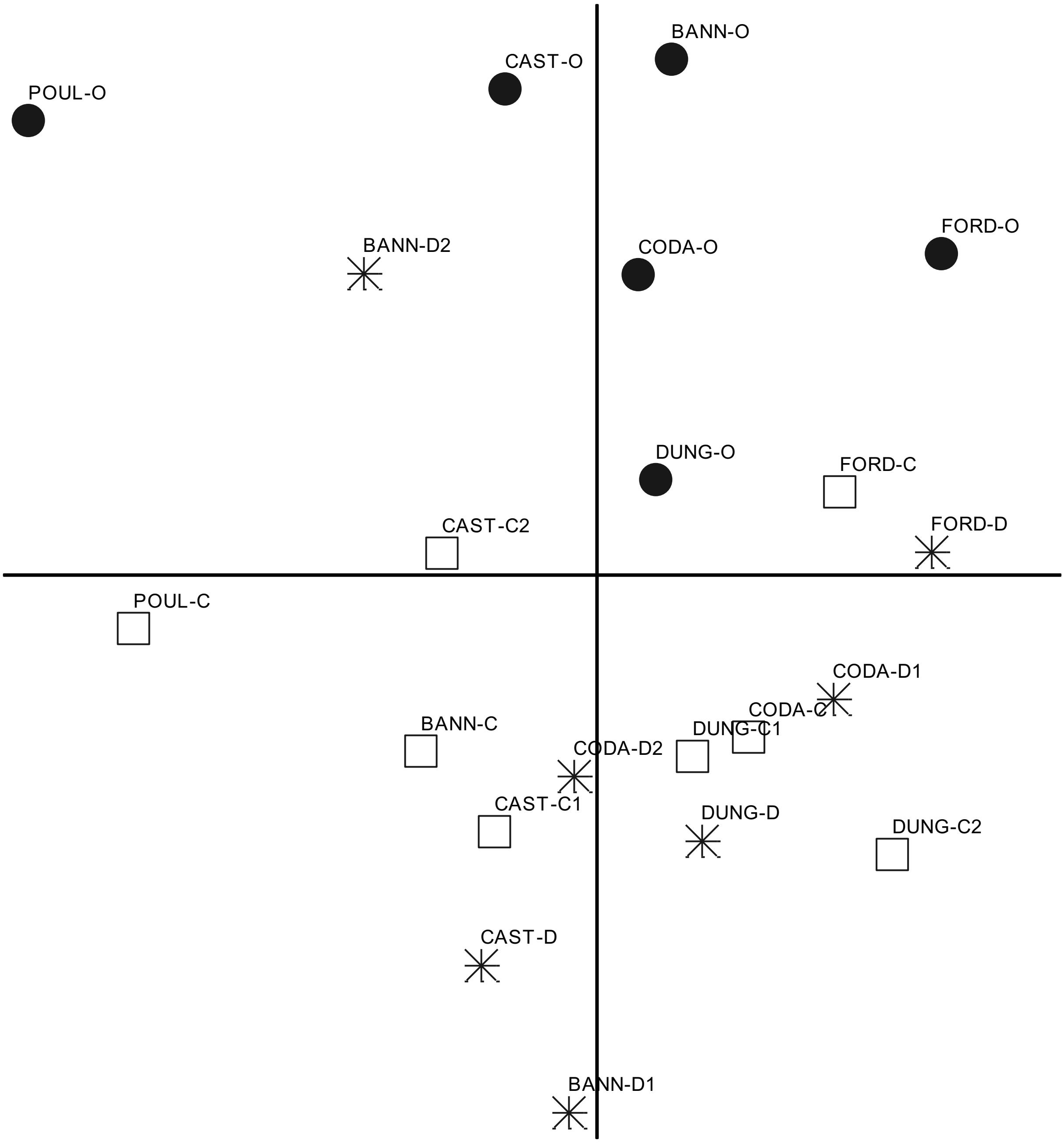


Figure 6.2 - Non-metric multidimensional scaling analysis ordination of variation in the all species assemblage across all sites. The stress was 15.3 and the final instability was 0.00001. The r^2 values are axis 1 0.24, and axis 2 0.59. Oyster trestle groups are indicated by closed circles, close controls by open squares and distant controls by asterisks.

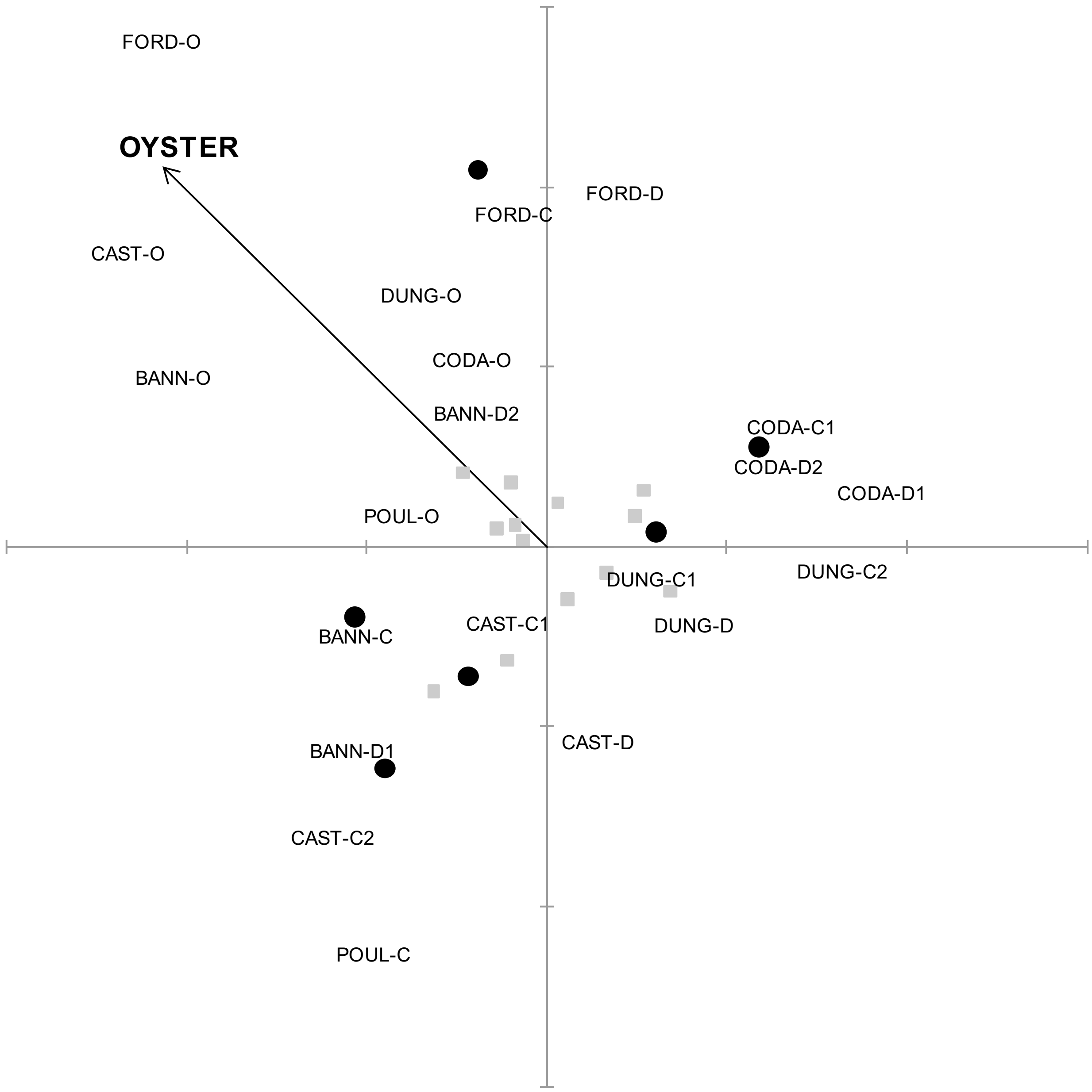


Figure 6.3 – CCA triplot of assemblage variation in intertidal invertebrate feeding waterbirds. Centroids of the SITE factor are shown as large closed circles and species are shown as small grey squares.

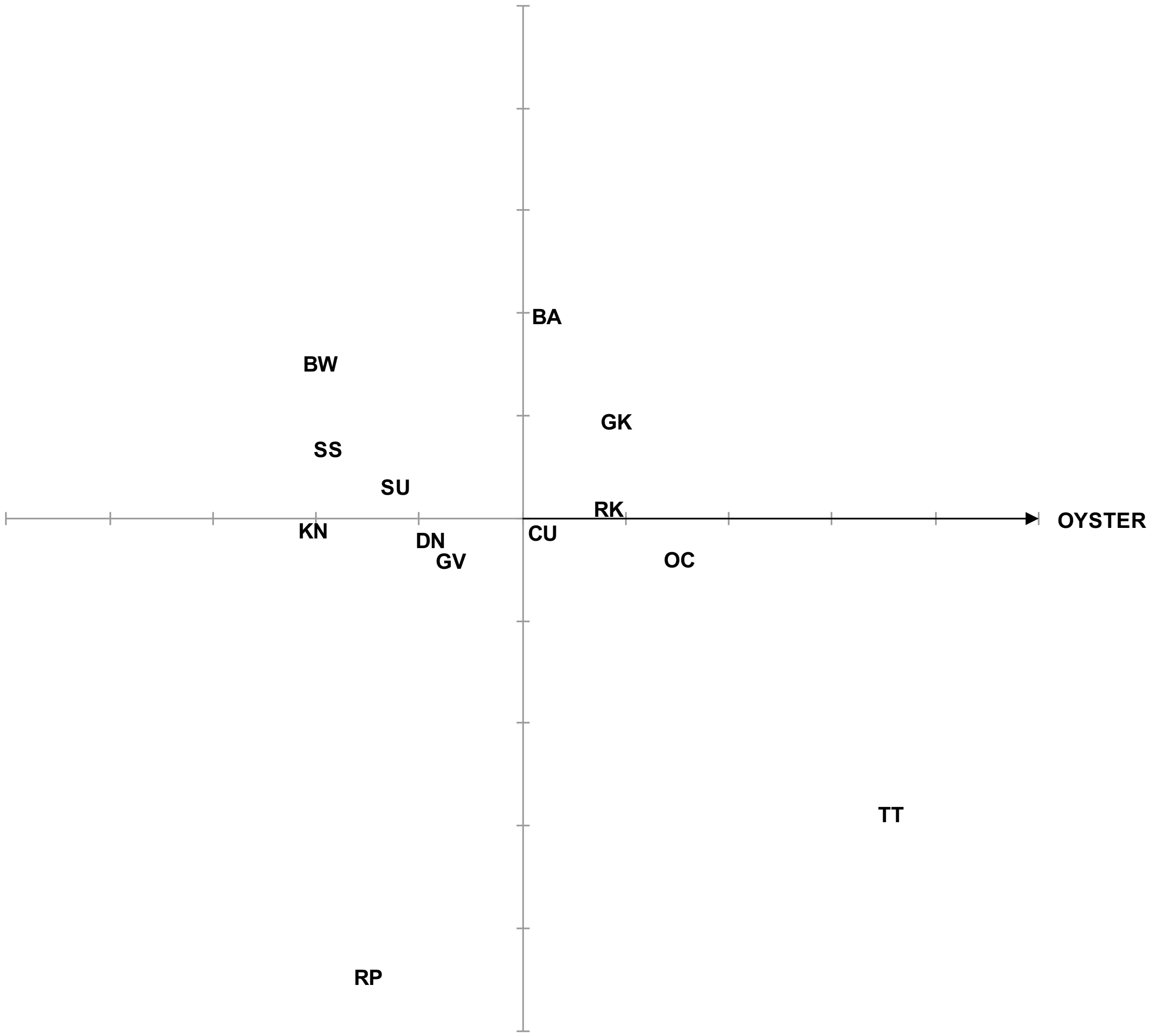
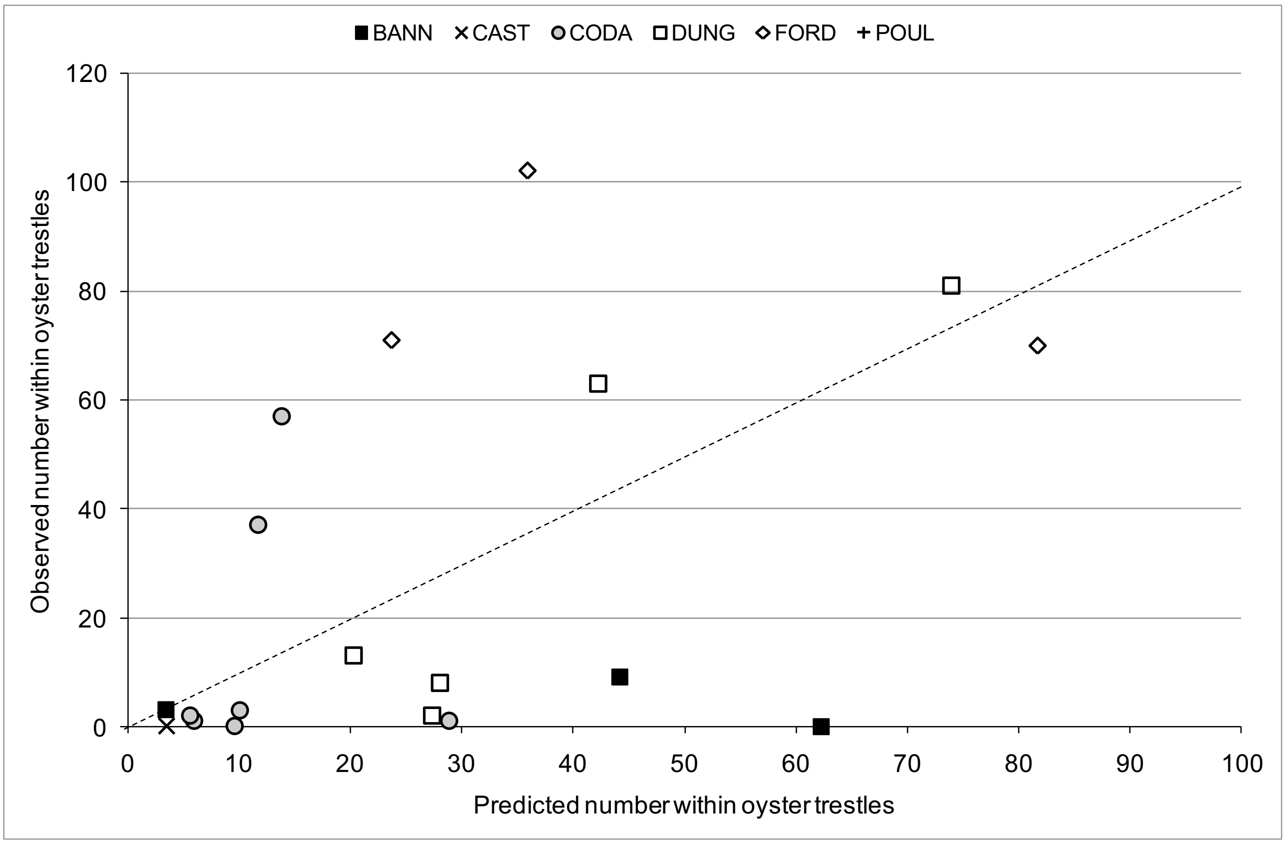


Figure 6.4 – Arrangement of species in the partial CCA of assemblage variation in intertidal invertebrate feeding waterbirds with the SITE factor as a covariable.



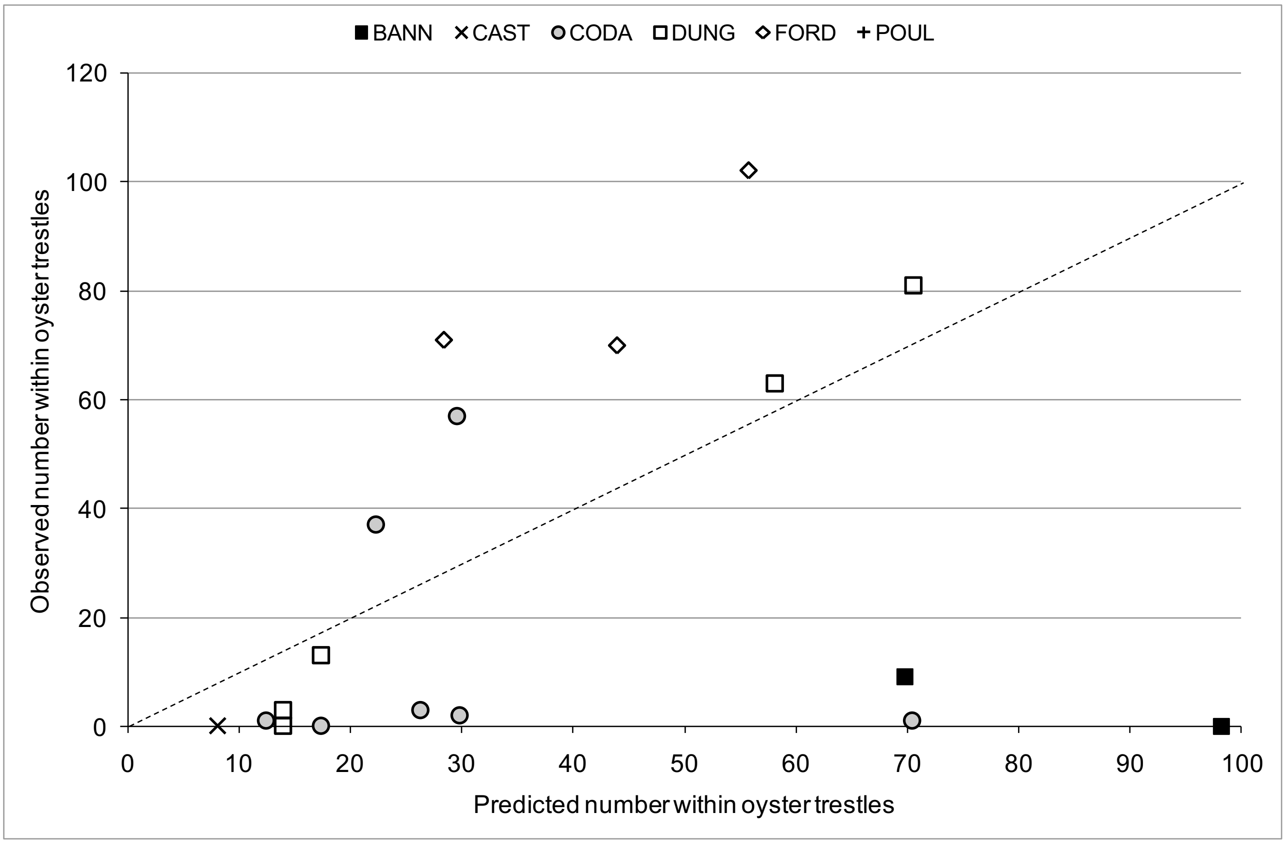


Figure 6.5 - Observed compared to predicted occurrence of Light-bellied Brent Goose within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). Some data points with observed values of 0 and 2 have been displaced slightly for clarity in the lower graph.

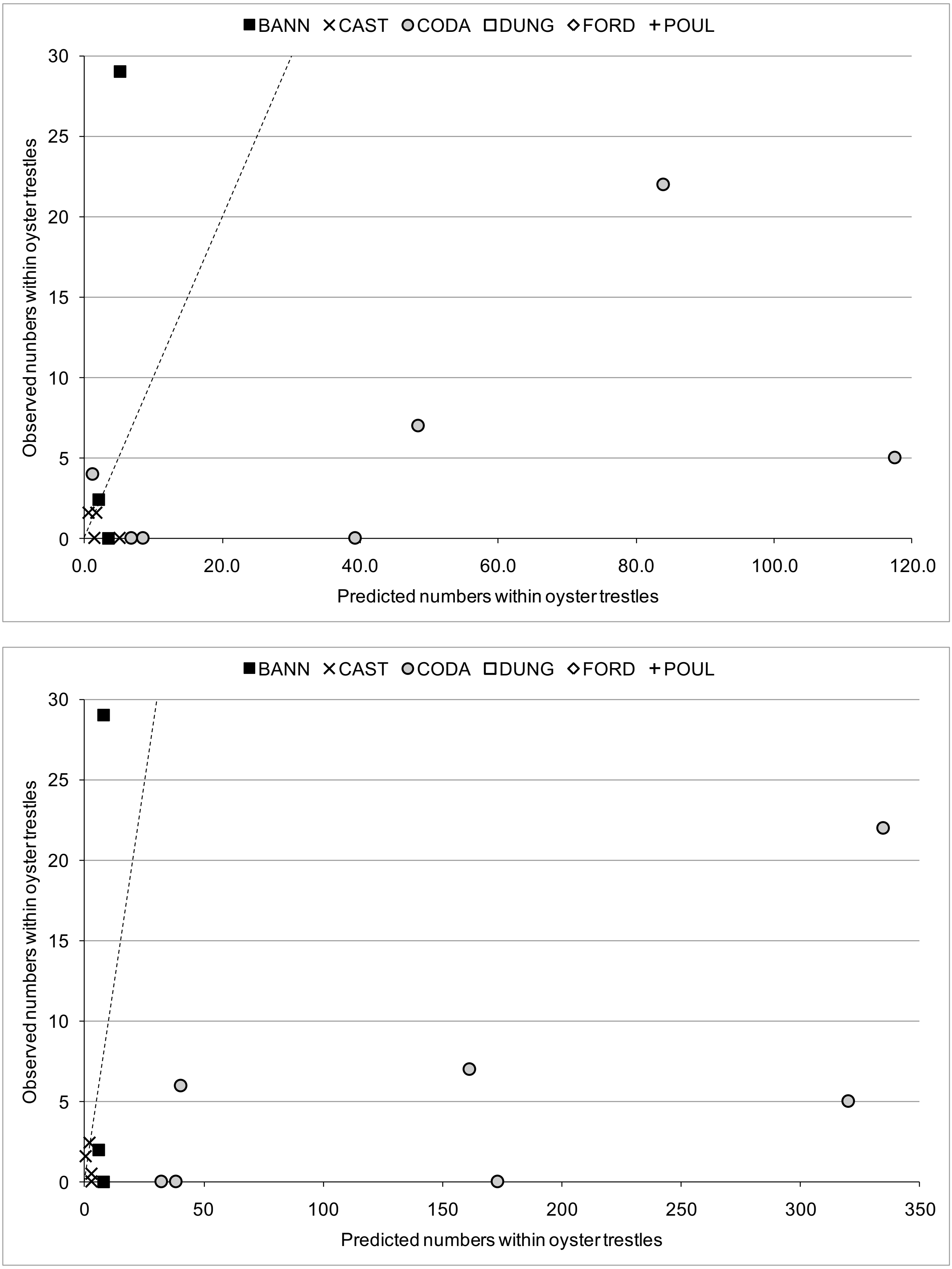
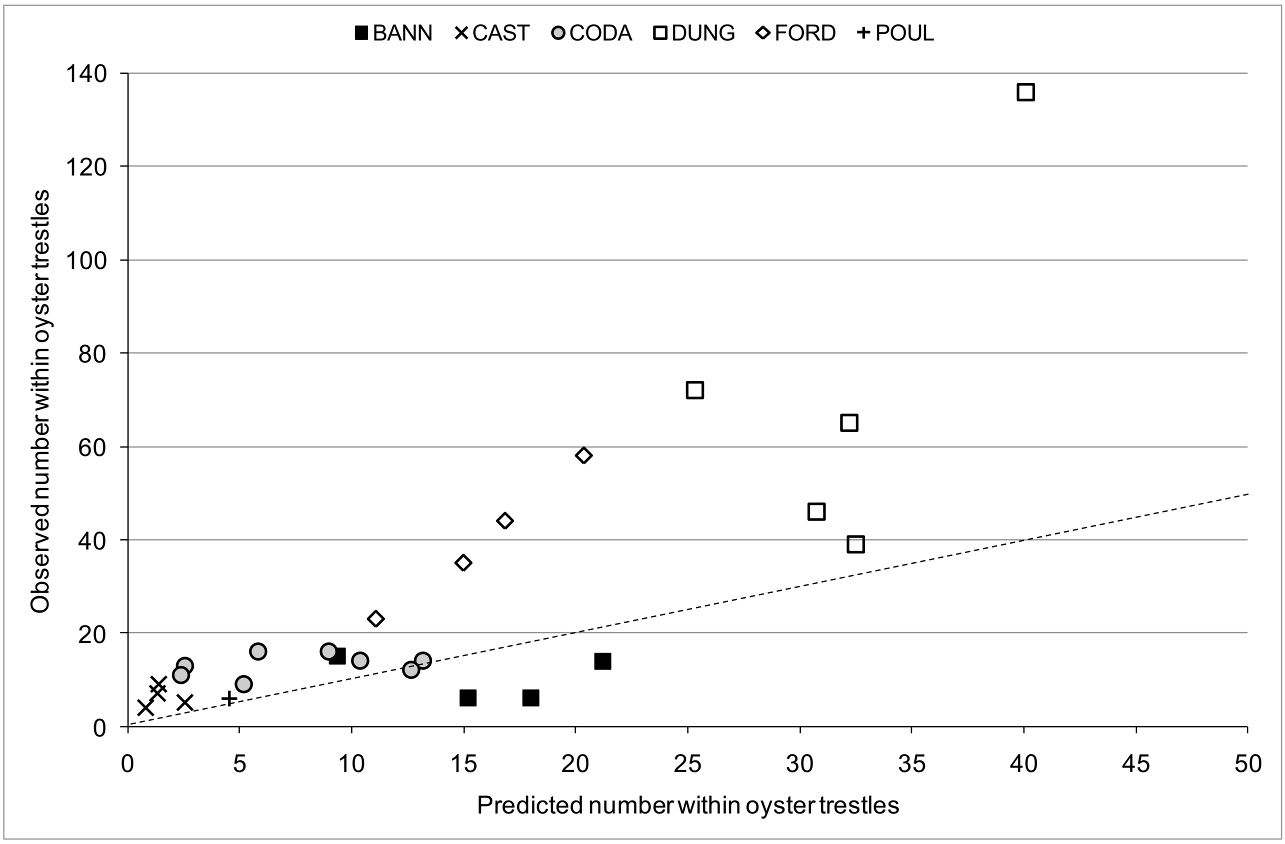


Figure 6.6 - Observed compared to predicted occurrence of Wigeon within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). Some data points with observed values of 0-3 have been displaced slightly for clarity.



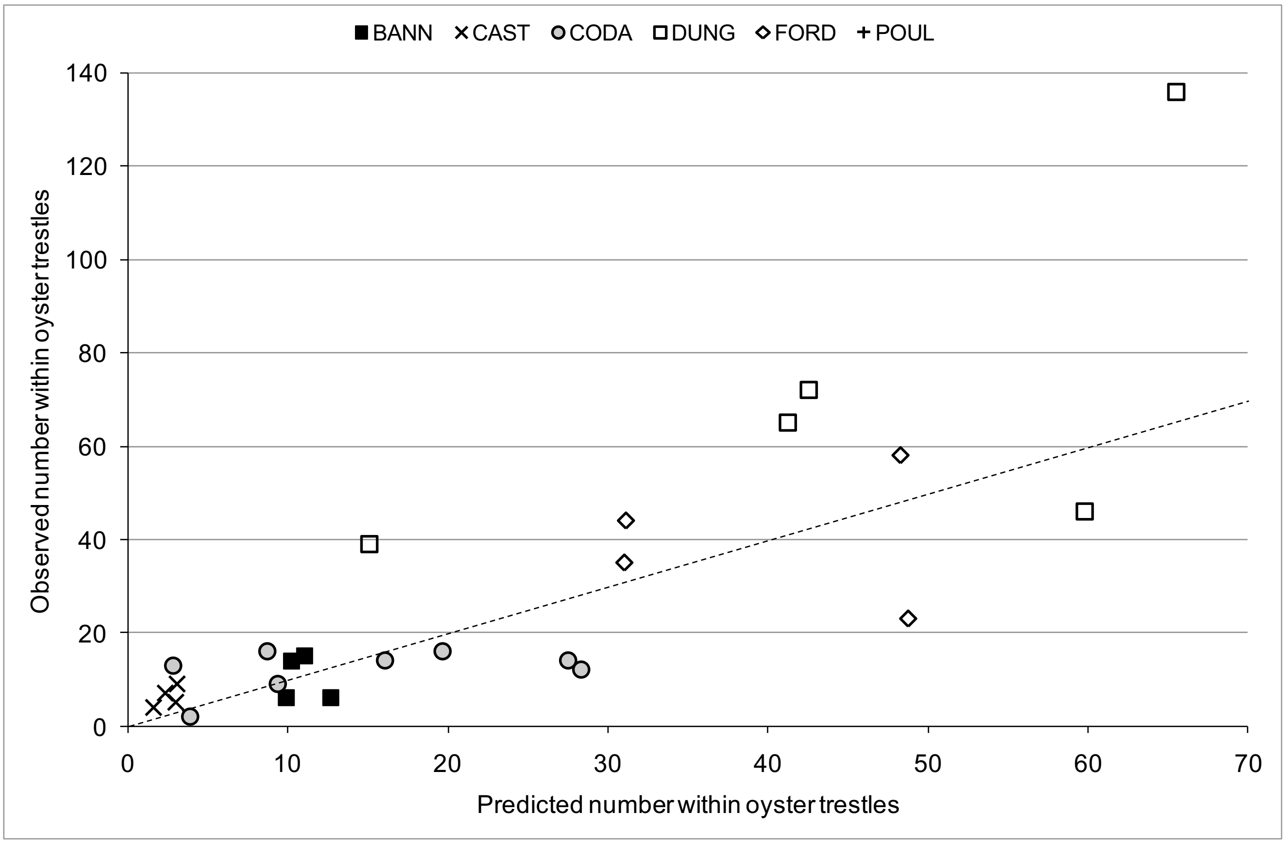
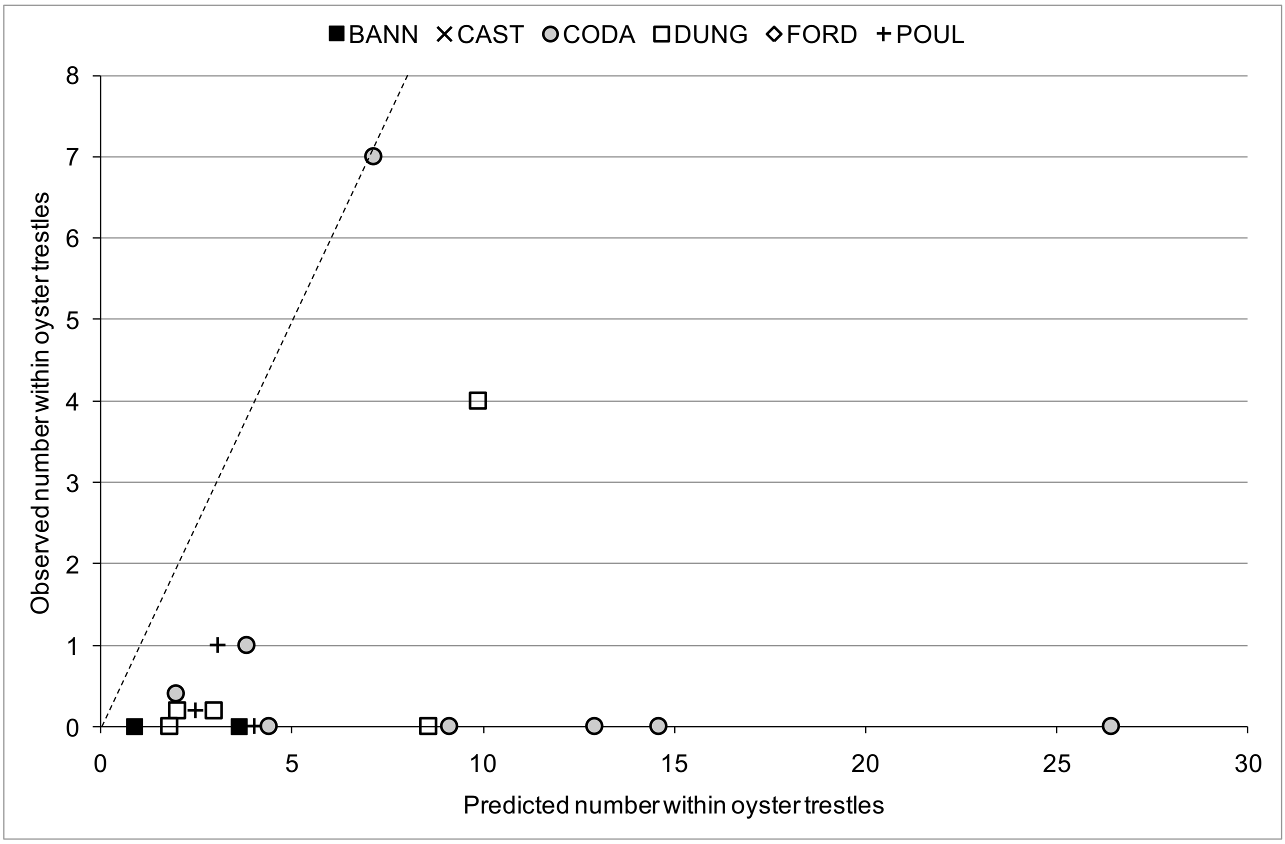


Figure 6.7 - Observed compared to predicted occurrence of Oystercatcher within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph).



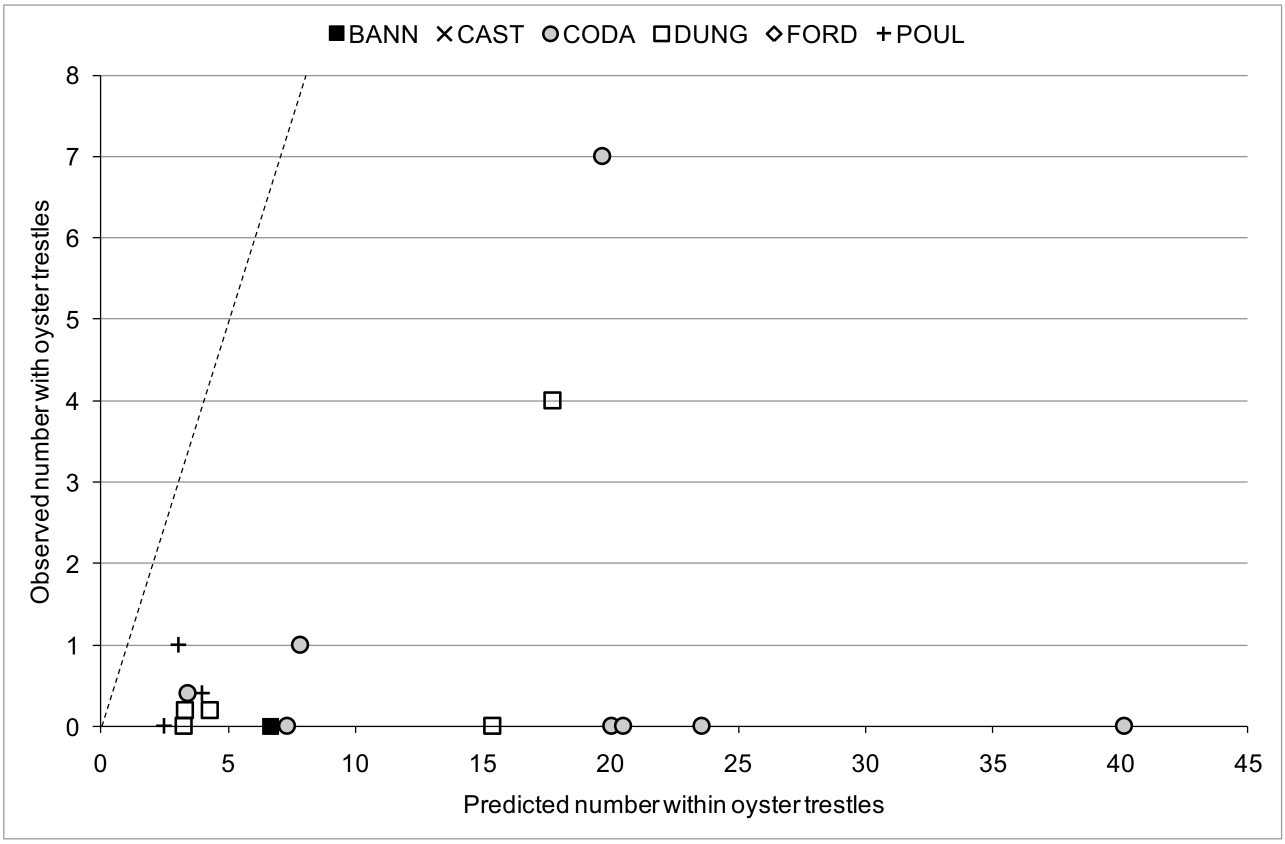
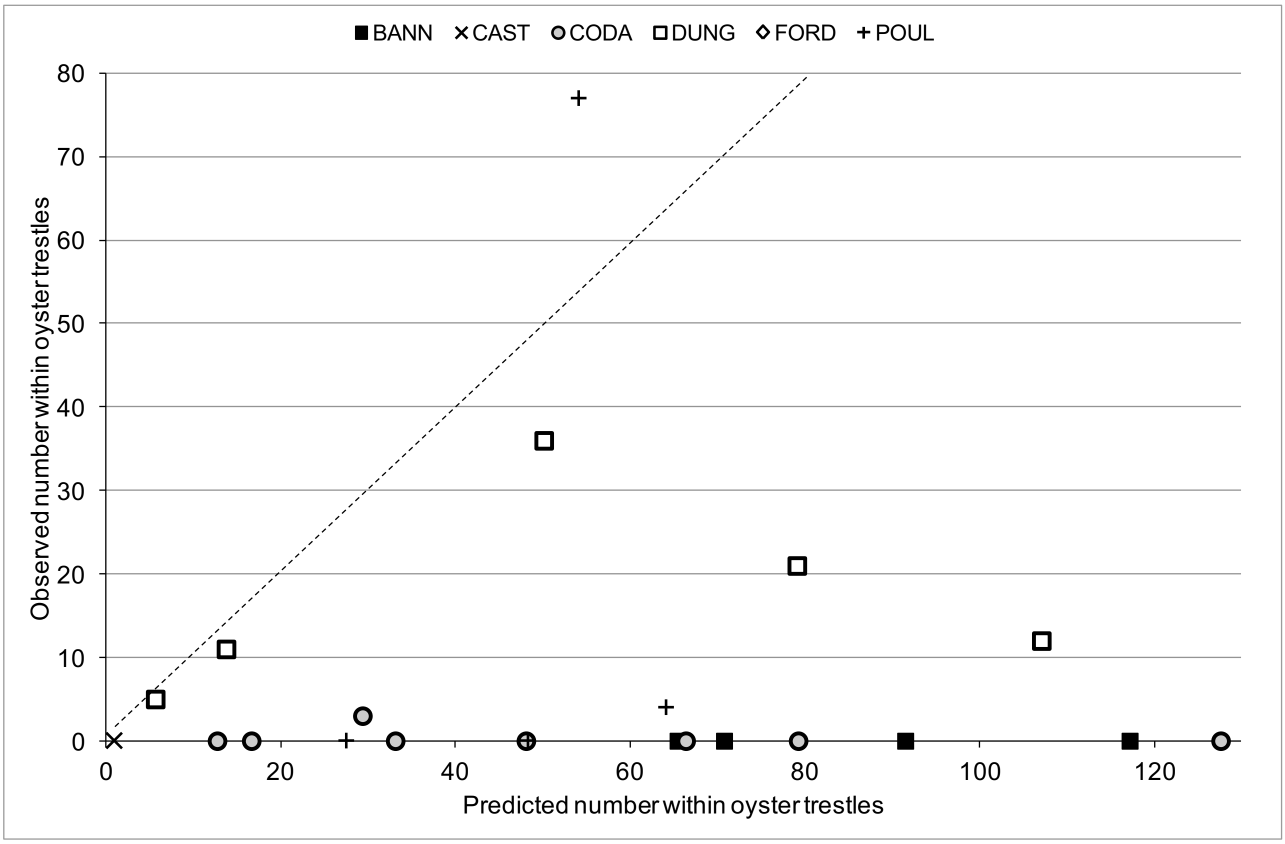


Figure 6.8 - Observed compared to predicted occurrence of Grey Plover within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). Some data points with zero observed values have been displaced slightly for clarity.



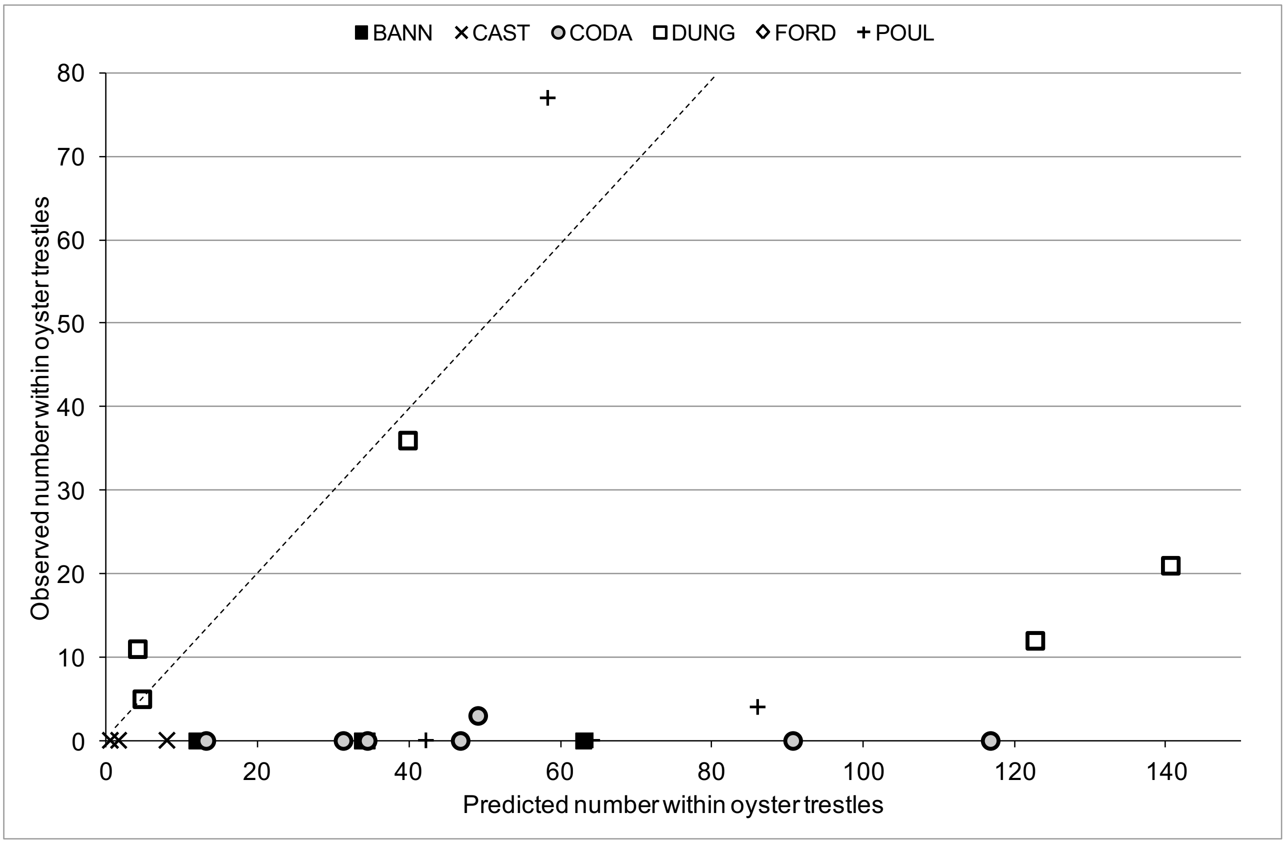
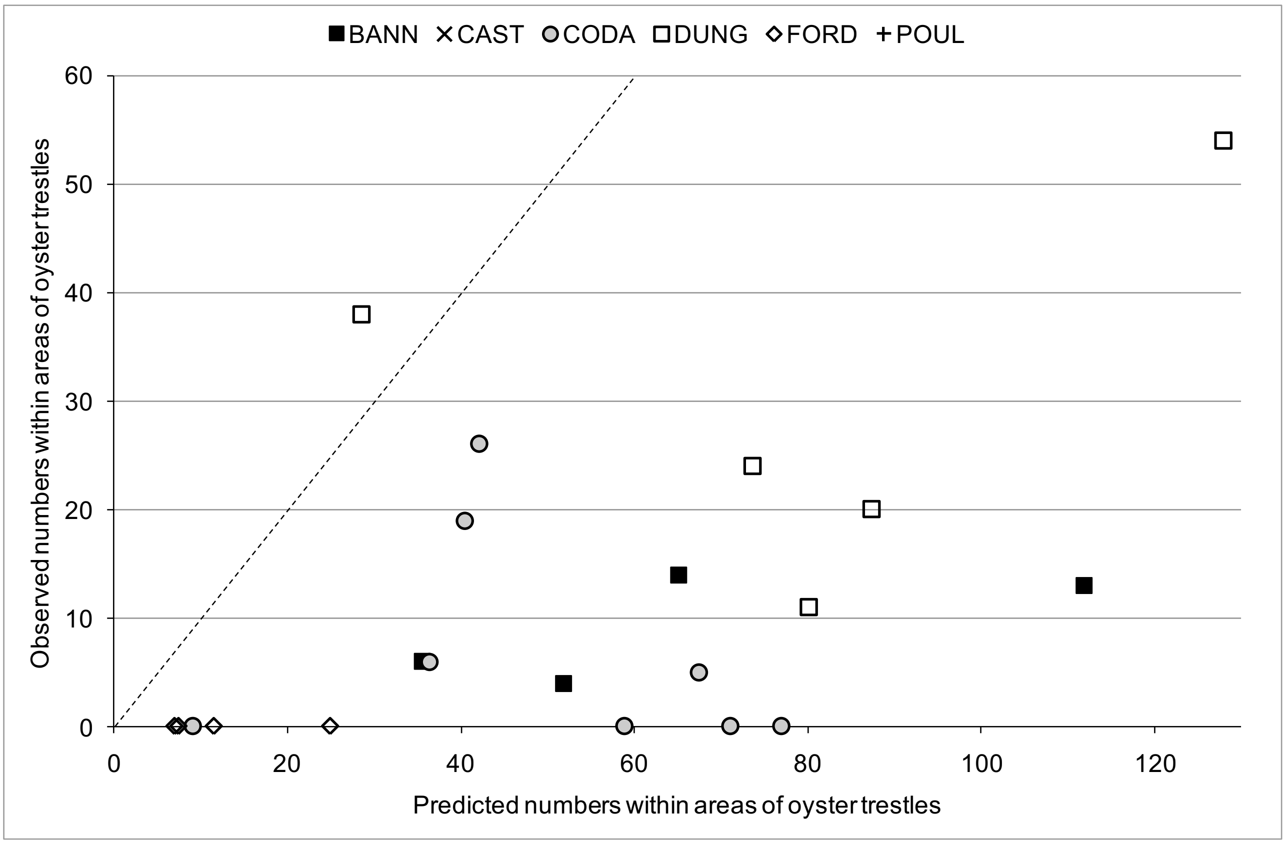


Figure 6.9 - Observed compared to predicted occurrence of Dunlin within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). One data point for Ballymacoda (359, 0) has been omitted from the lower graph to improve the clarity of the graph.



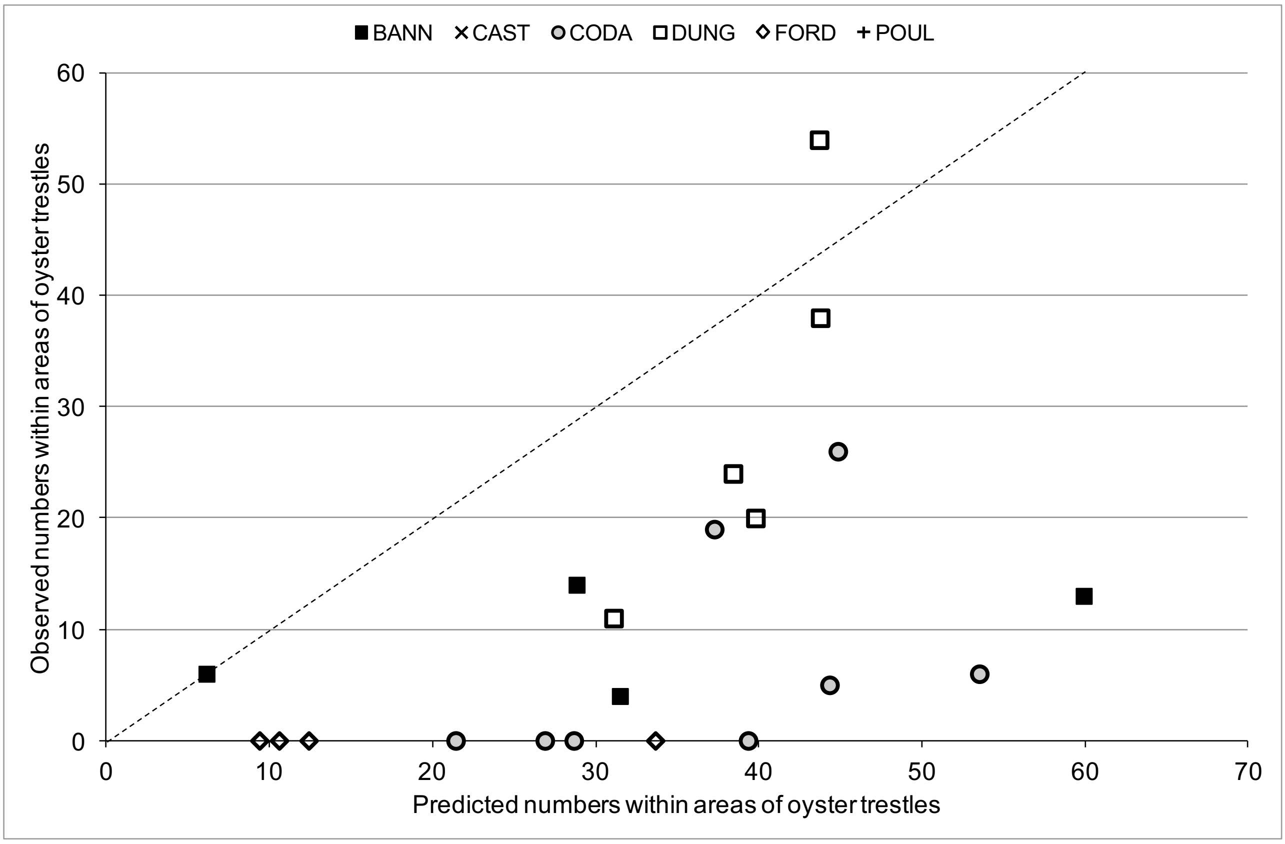
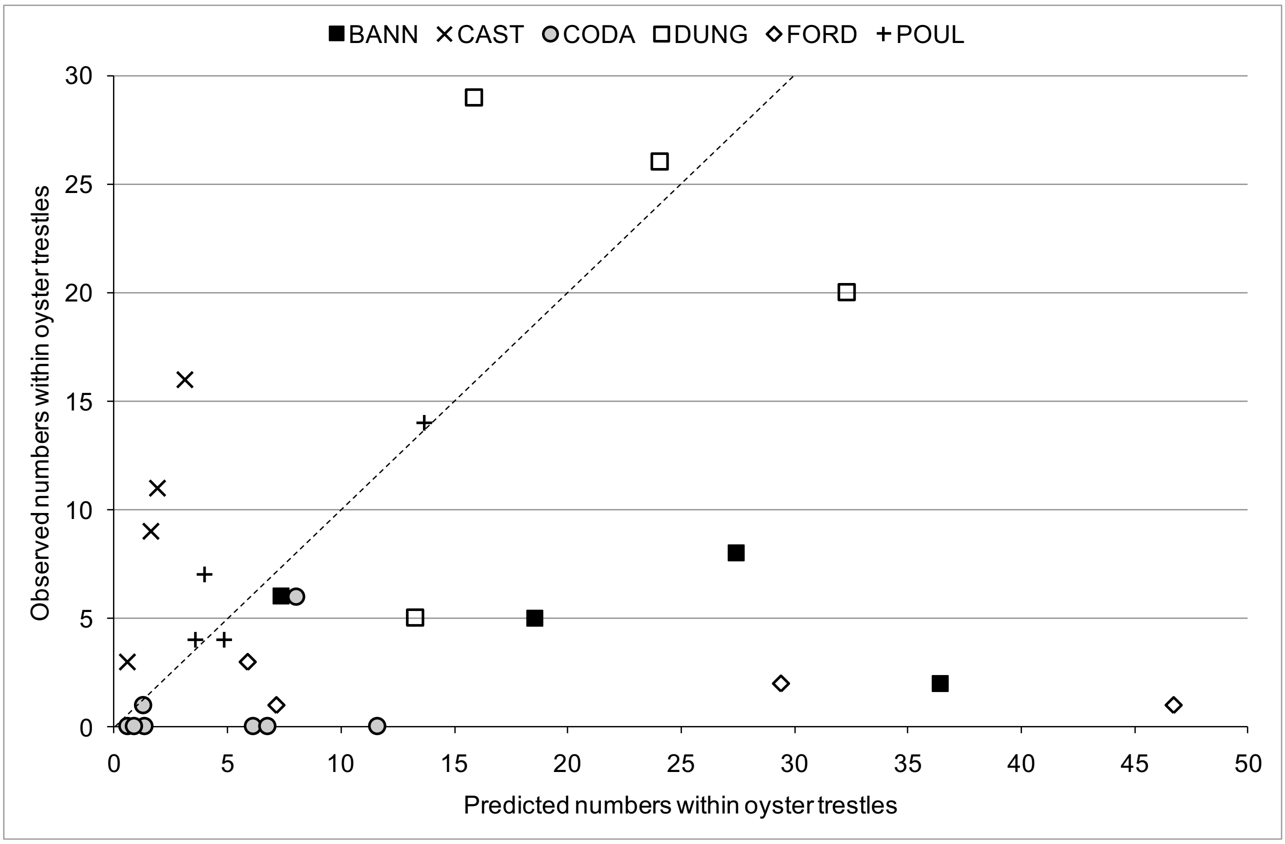


Figure 6.10 - Observed compared to predicted occurrence of Bar-tailed Godwit within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph).



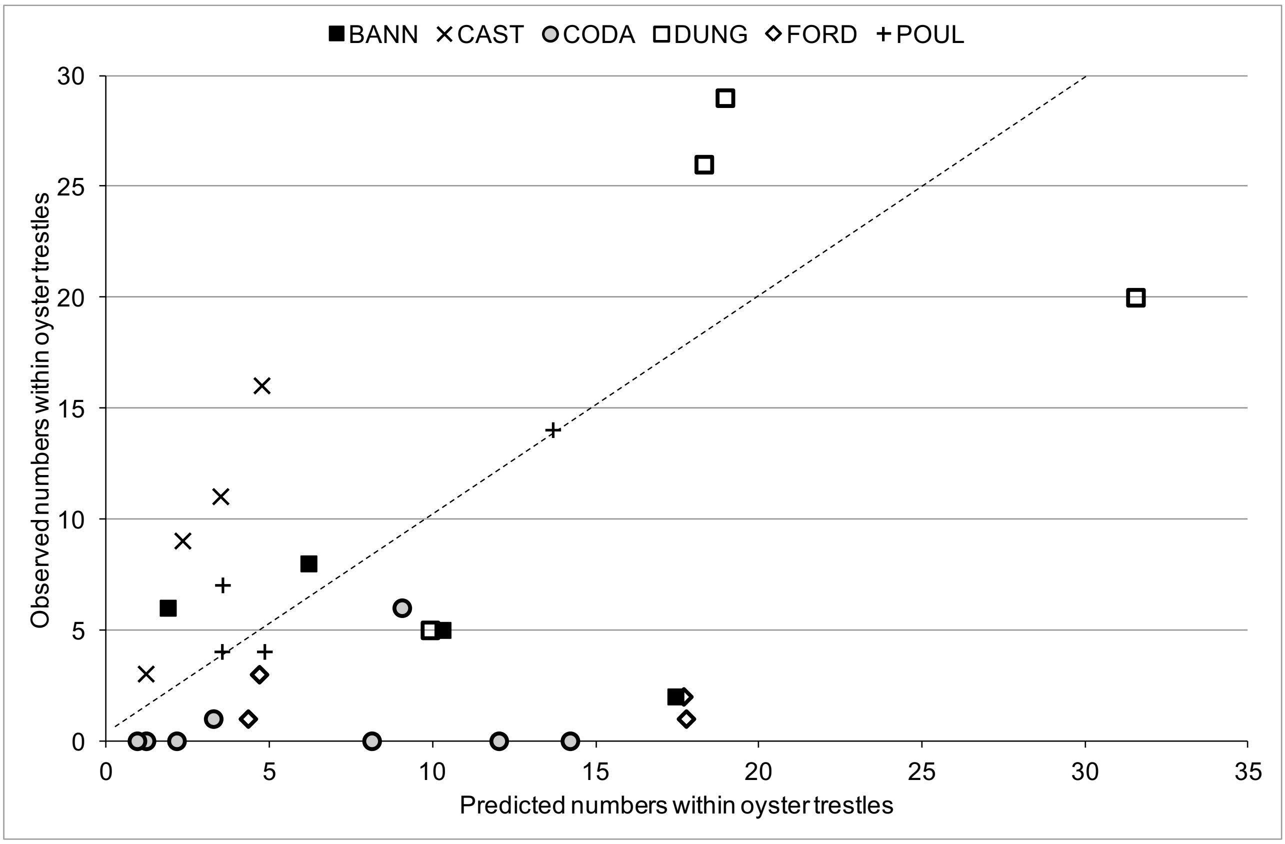
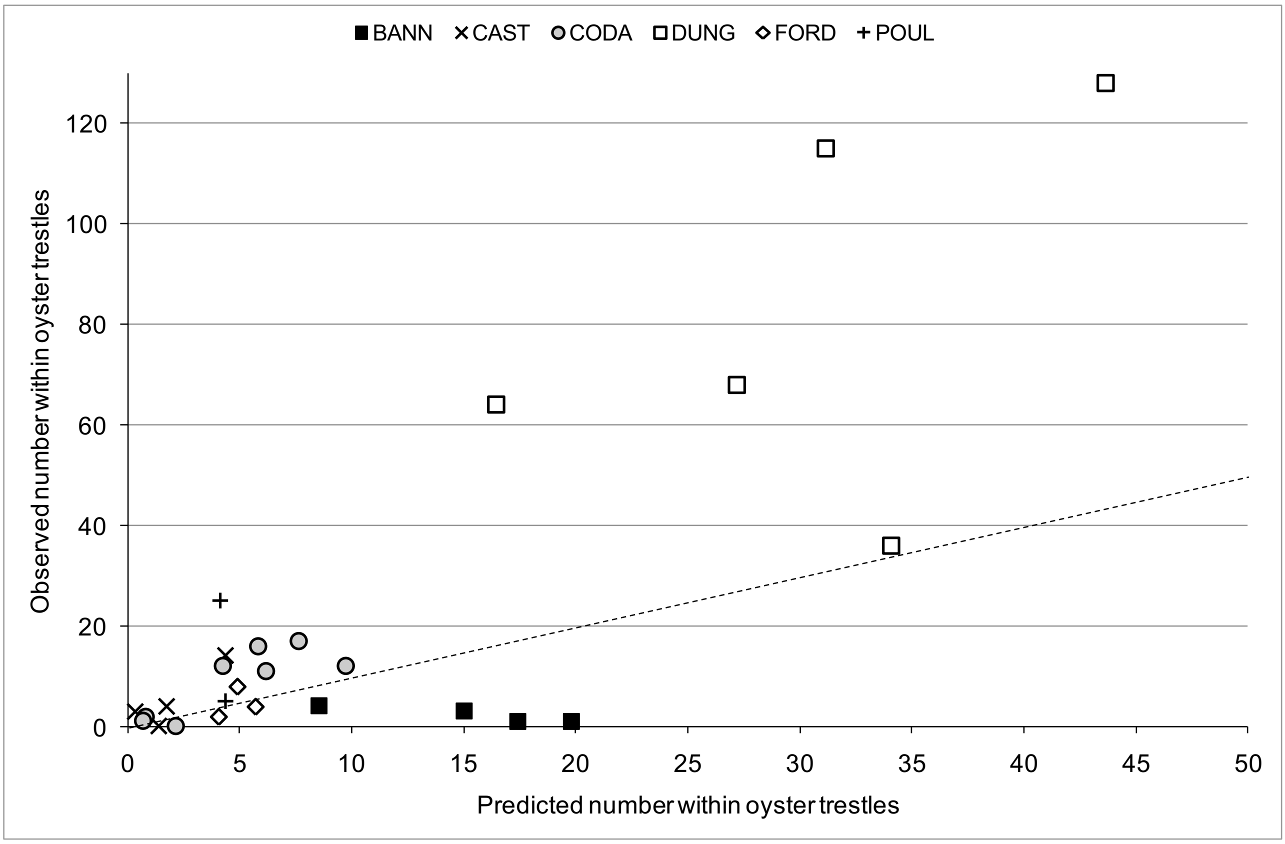


Figure 6.11 - Observed compared to predicted occurrence of Curlew within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph).



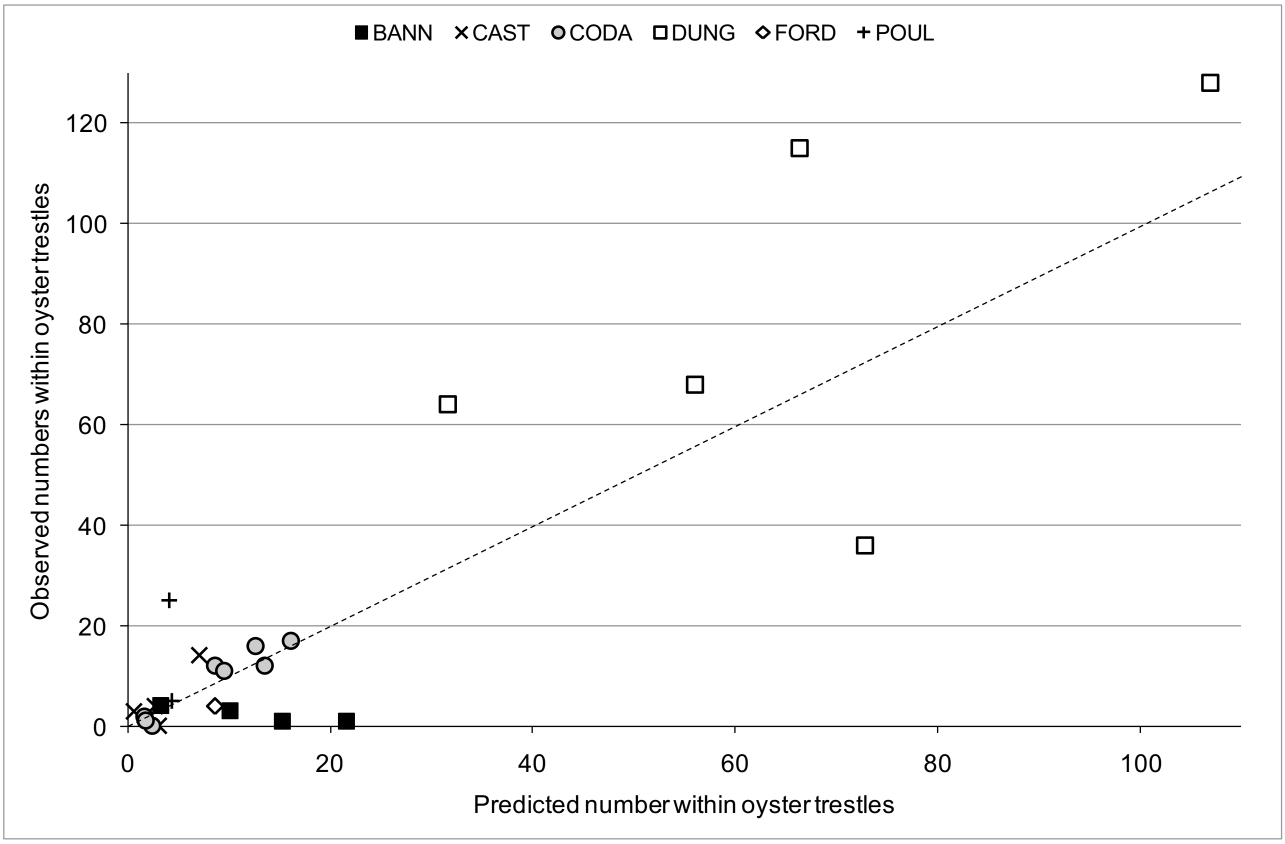
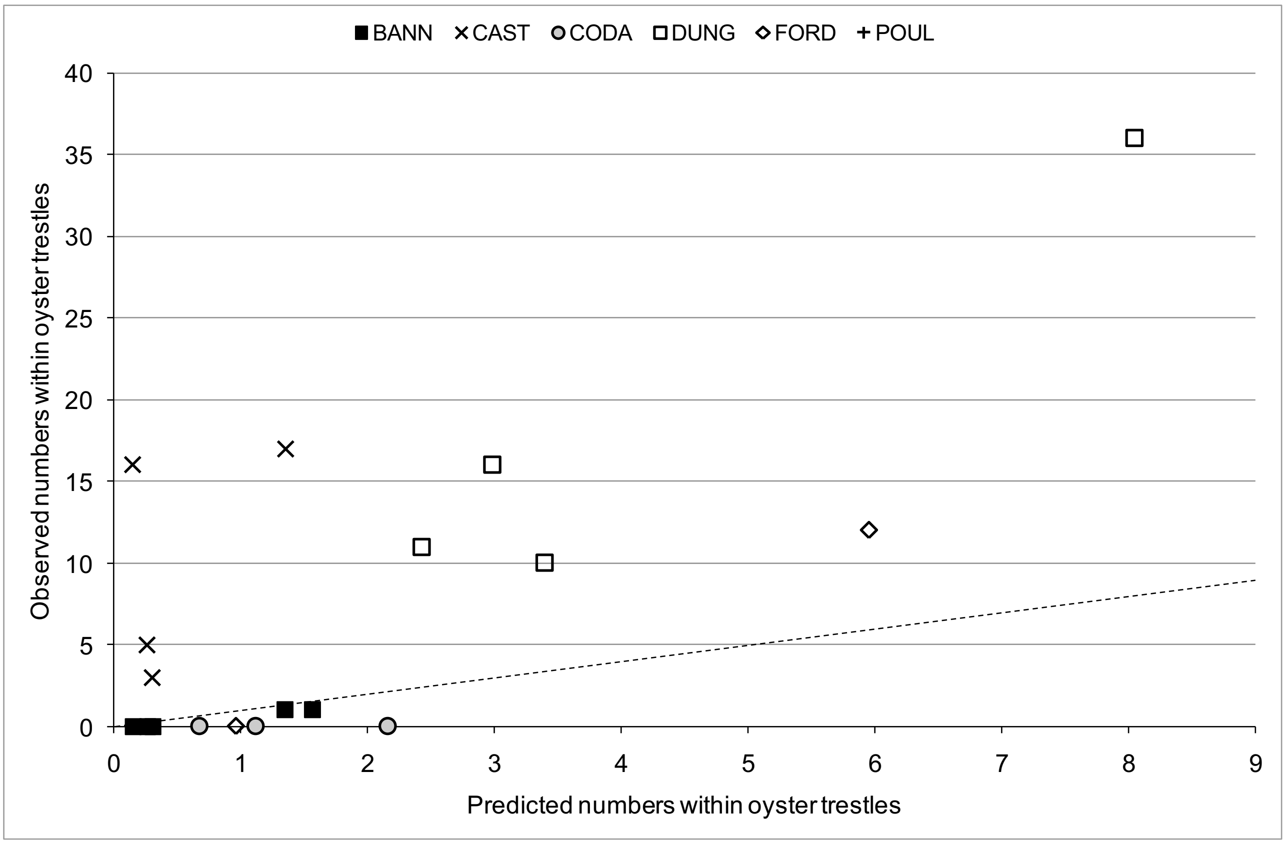


Figure 6.12 - Observed compared to predicted occurrence of Redshank within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph).



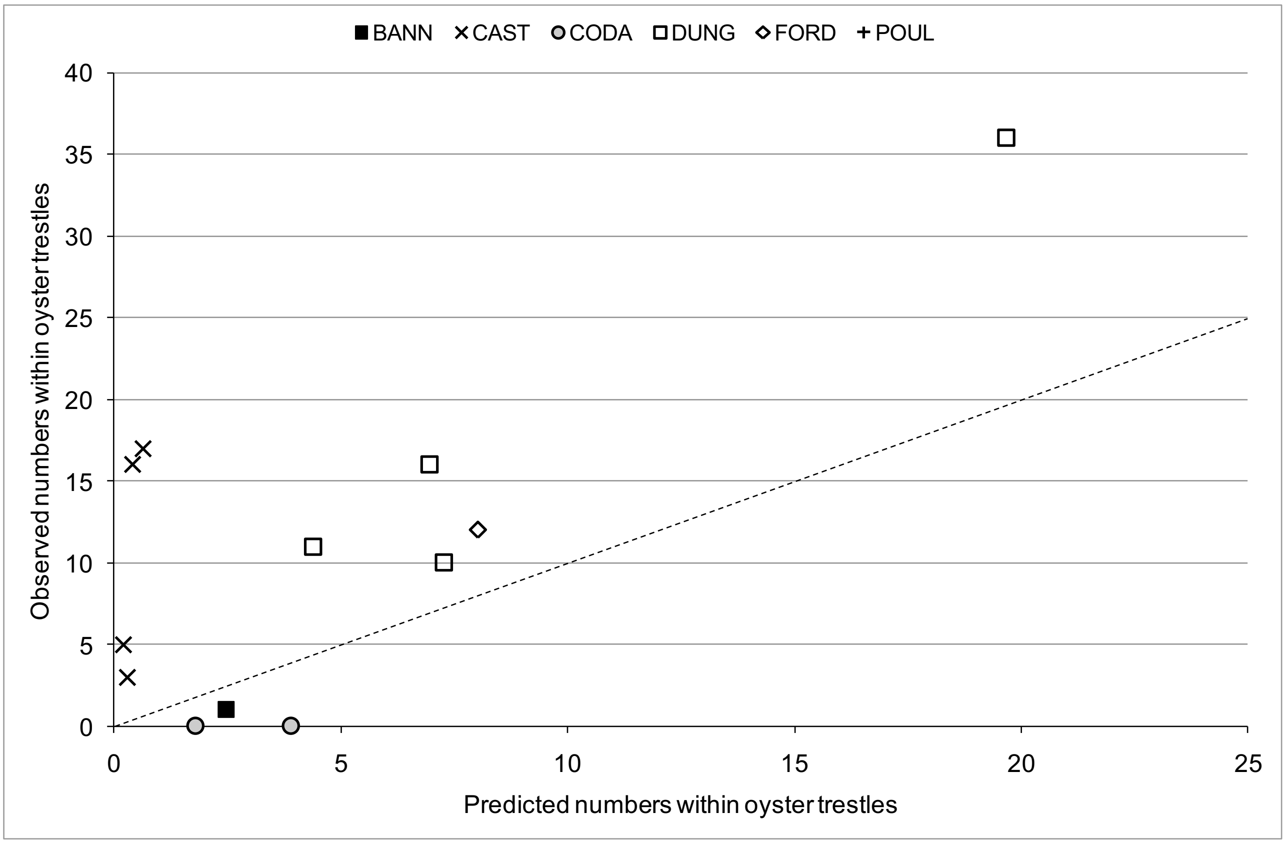
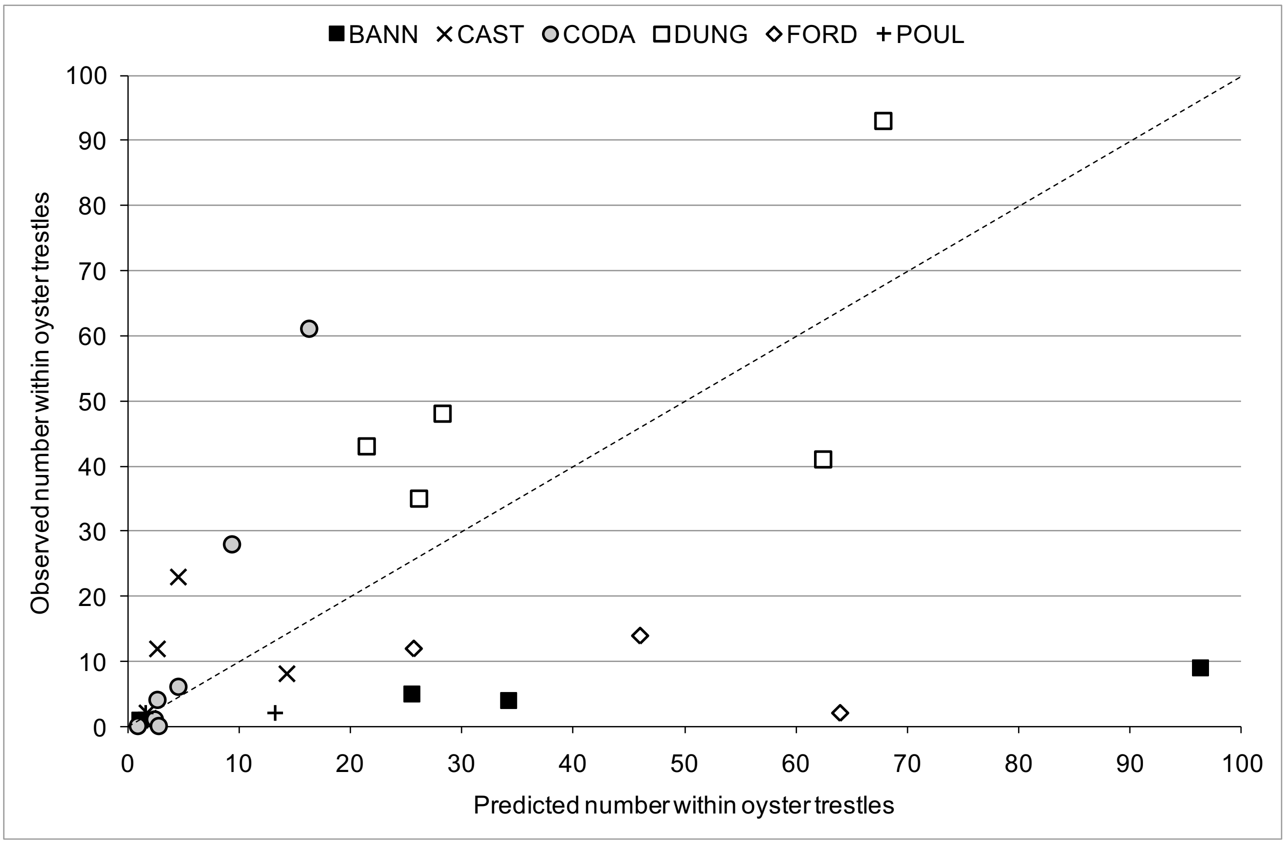


Figure 6.13 - Observed compared to predicted occurrence of Turnstone within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph).



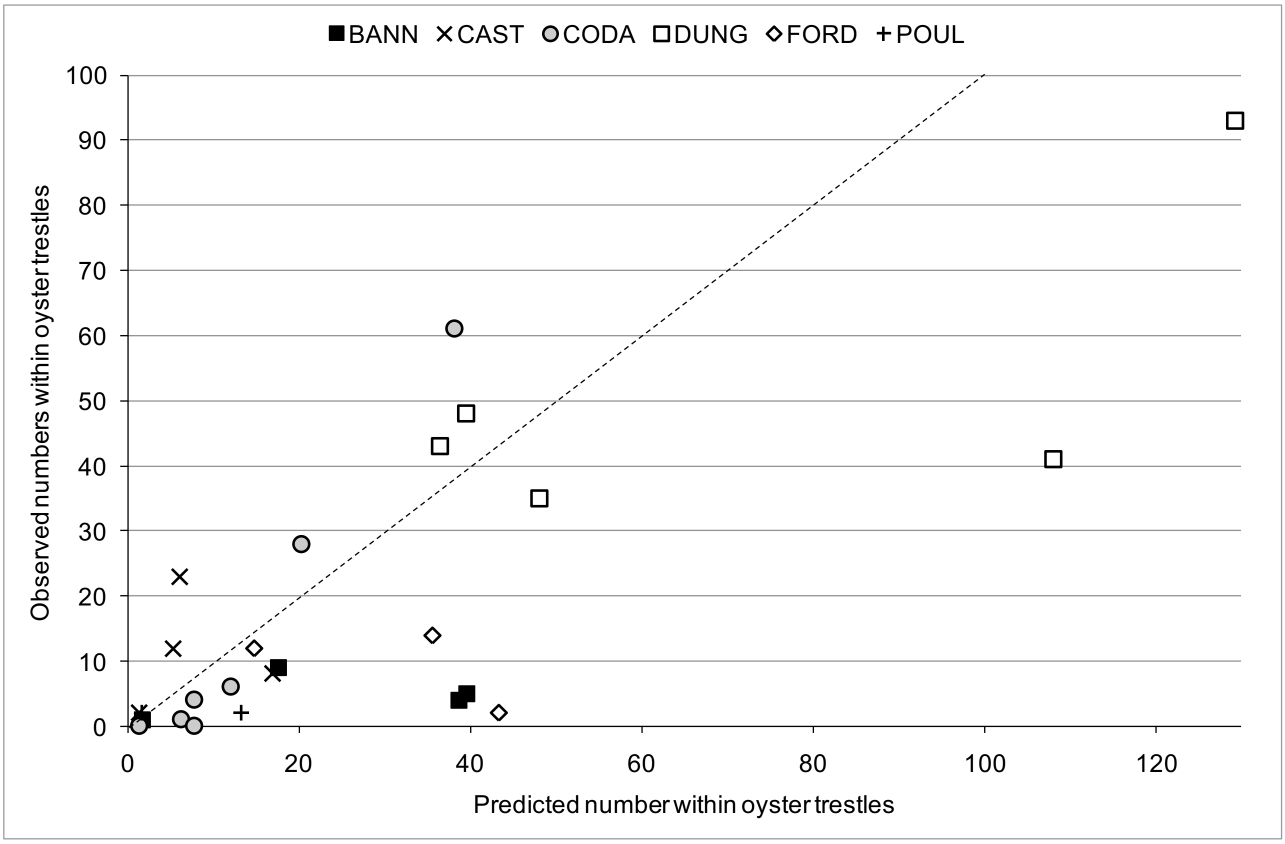
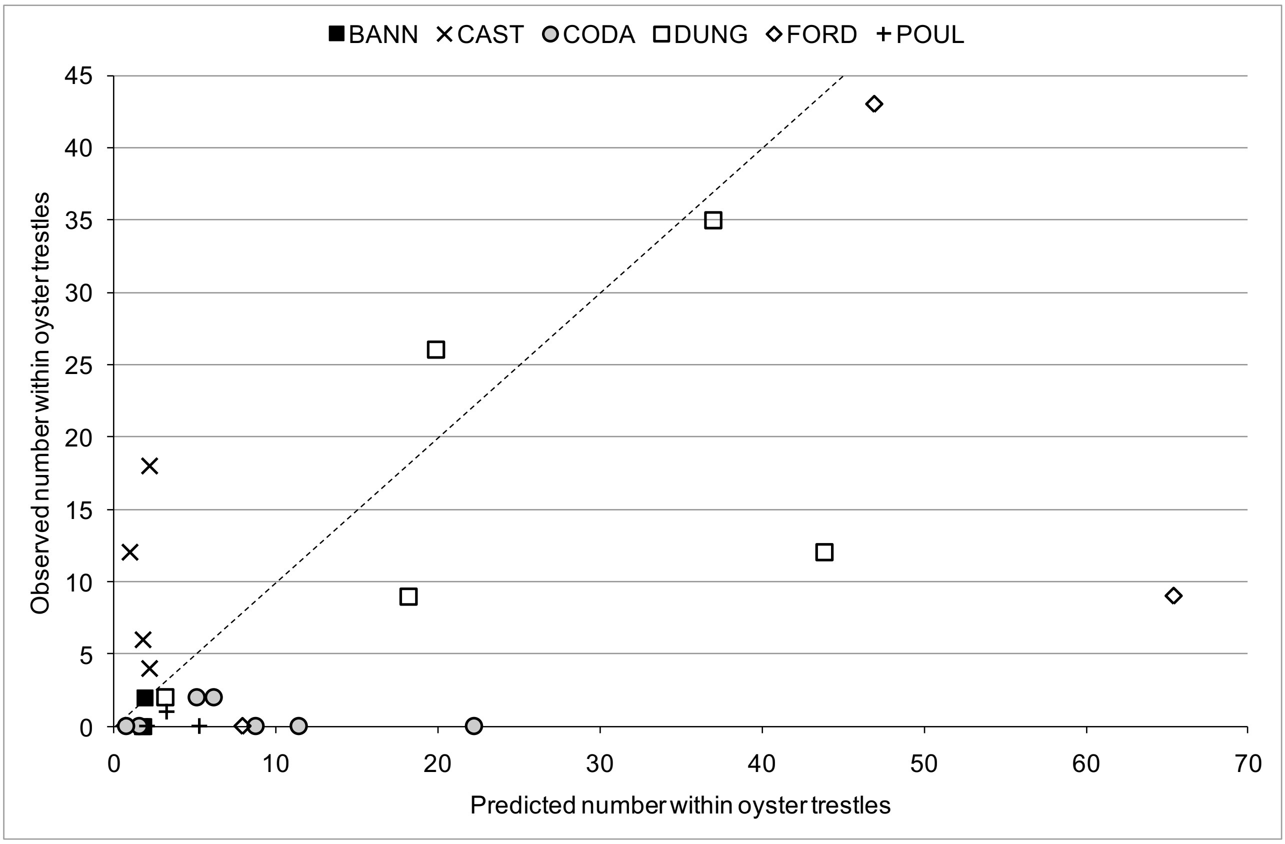


Figure 6.14 - Observed compared to predicted occurrence of Black-headed Gull within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). One data point for Waterford Harbour (237,101 in the upper graph; 311, 101 in the lower graph) has been omitted to improve the clarity of the graph.



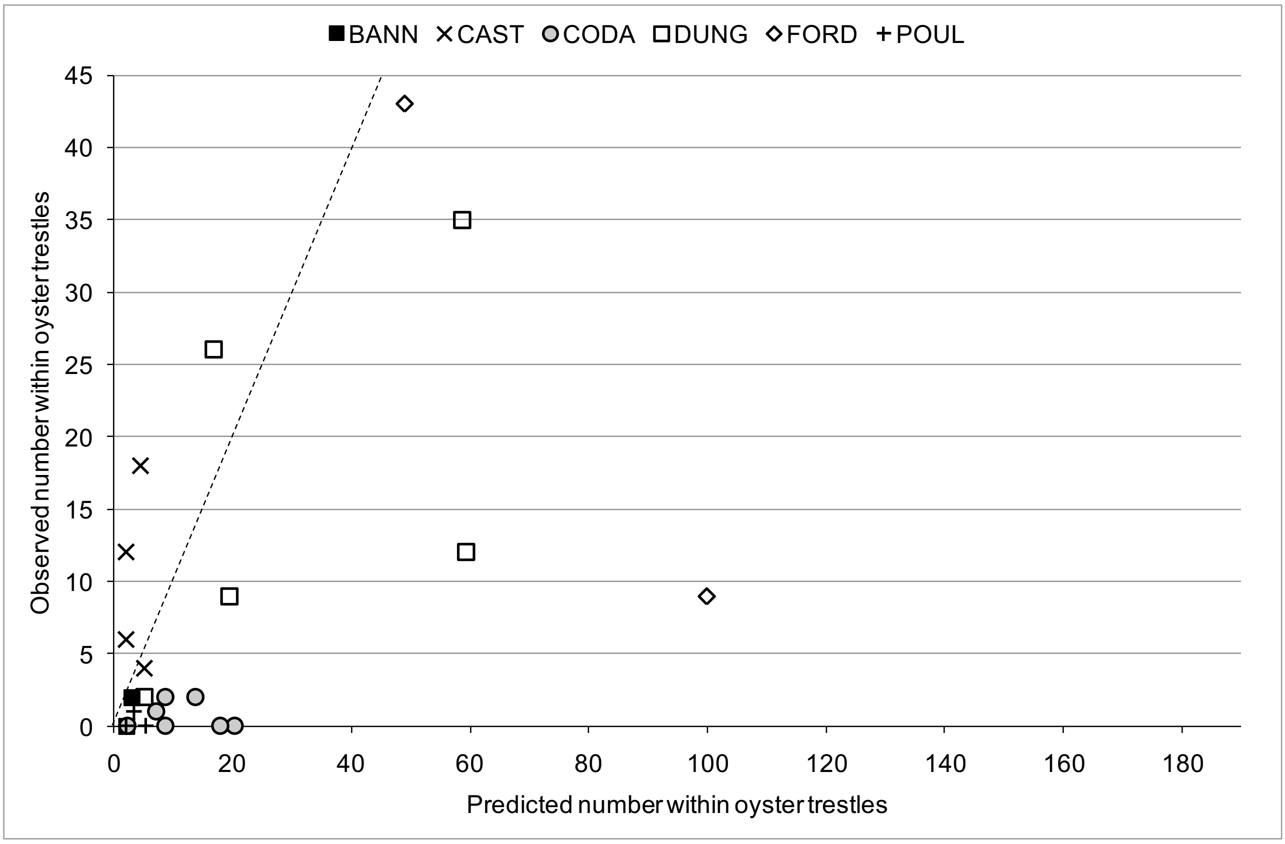
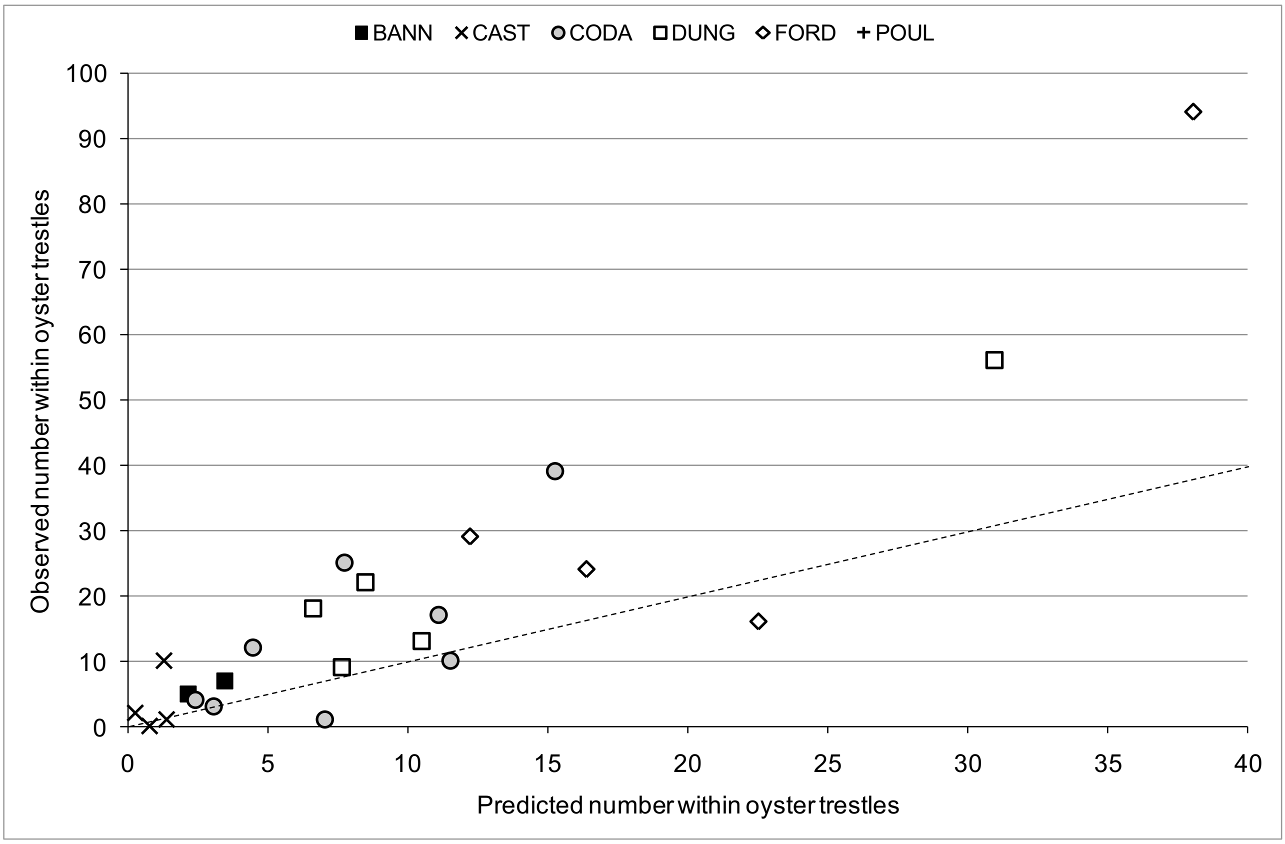


Figure 6.15 - Observed compared to predicted occurrence of Common Gull within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). One data point for Waterford Harbour (258, 0 in the upper graph; 340, 0 in the lower graph) has been omitted to improve the clarity of the graph.



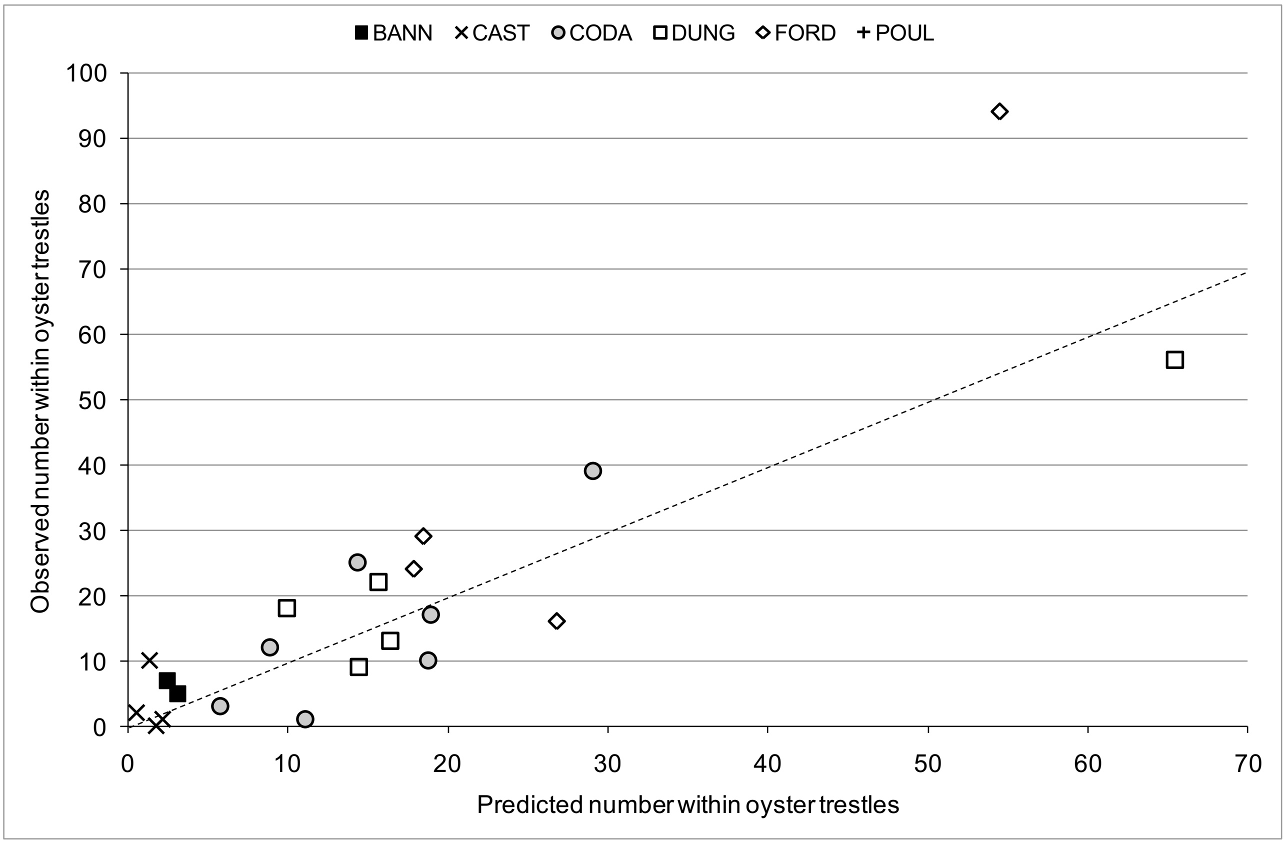
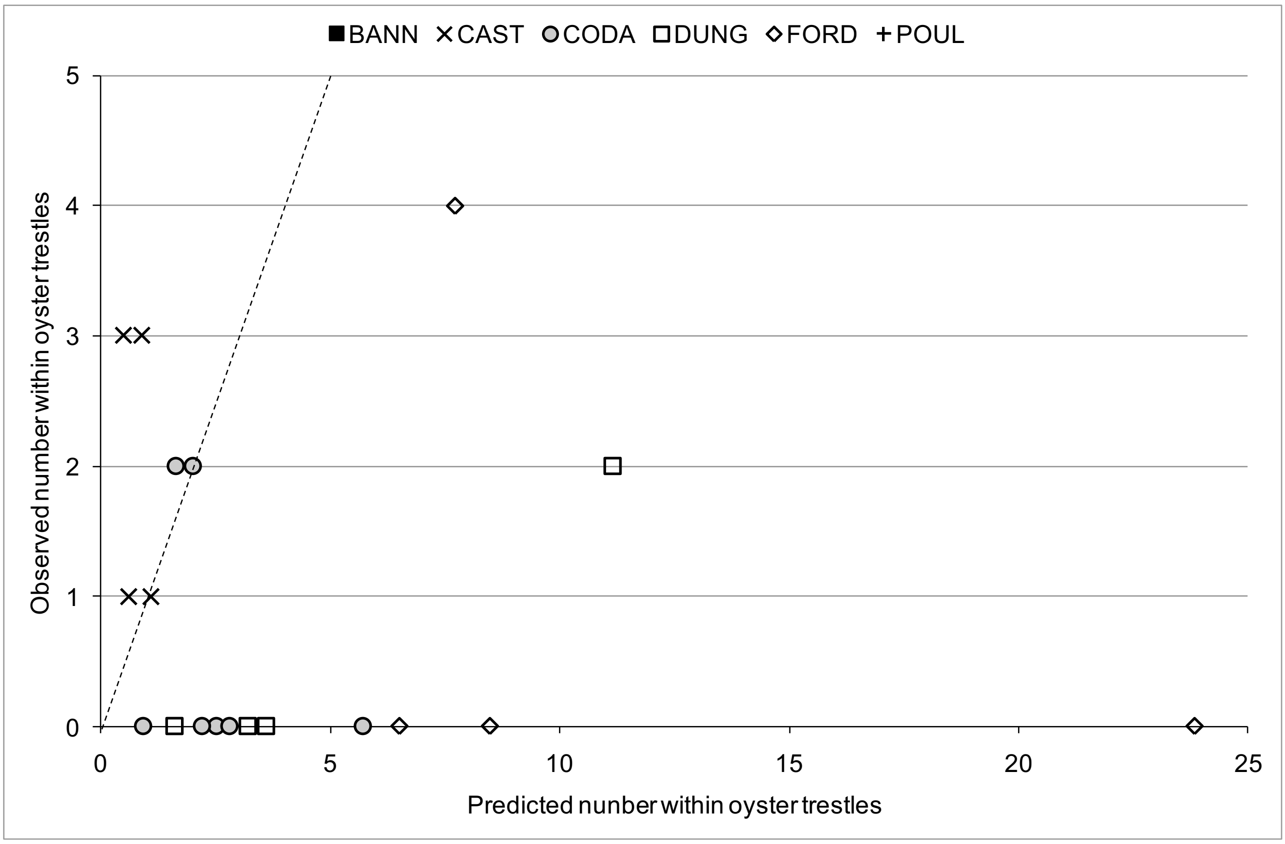


Figure 6.16 - Observed compared to predicted occurrence of Herring Gull within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph).



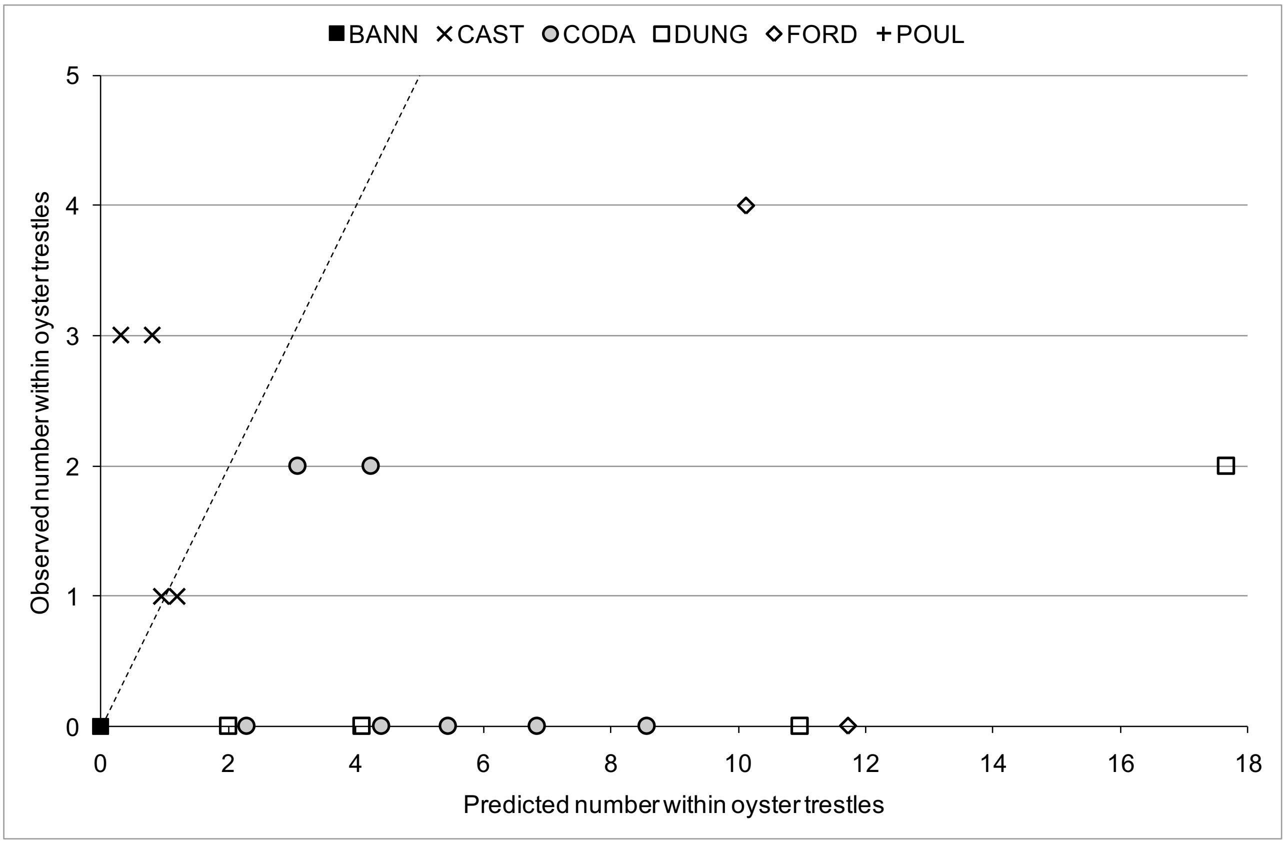


Figure 6.17 - Observed compared to predicted occurrence of Great Black-backed Gull within oyster trestle blocks using data from all sectors (upper graph) and close sectors (lower graph). Some data points with observed values of 0, 1 and 3 have been displaced slightly for clarity.

7. Results: Intensive study

Overview of count data.

7.1 Total counts on each count day at each site are shown in Appendix F. A total of 25 species were recorded across all the counts. Light-bellied Brent Goose, Oystercatcher, Dunlin, Bar-tailed Godwit, Redshank, Turnstone, Black-headed Gull, Common Gull, Herring Gull and Hooded Crow were recorded on all the counts (Table 7.1). Light-bellied Brent Goose, Oystercatcher, Dunlin, Bar-tailed Godwit, Redshank, Black-headed Gull and Common Gull occurred in sizeable numbers, with mean counts of over 50. Oystercatcher, Bar-tailed Godwit and Redshank showed relatively low variation in numbers across the counts with coefficients of variation of 35% or less in the counts excluding OY1.

7.2 Light-bellied Brent Goose, Bar-tailed Godwit, Curlew and Herring Gull all showed a strong association with the tideline, with little variation between counts in the percentage of birds on the tideline with coefficients of variation of 15% or less (Table 7.2). Black-headed Gull and Common Gull also had high mean percentages on the tideline, but with larger variation between counts.

7.3 Most Light-bellied Brent Goose and waders recorded were feeding (Table 7.2). However, Light-bellied Brent Goose, Dunlin and Turnstone had relatively high variation between counts, reflecting the fact that roosting flocks were recorded on a few counts. The gull species had lower percentages feeding, with the majority of Herring Gulls recorded roosting.

7.4 A total of 16 species were recorded on trestles during the main counts (Table 7.3). Light-bellied Brent Goose, Oystercatcher, Herring Gull and Hooded Crow were the most abundant species on trestles, while birds on trestles also represented relatively high percentages of the total count for Turnstone.

Table 7.1 – Mean counts.

Species	Excluding OY1			Including OY1		
	Mean	SD	n	Mean	SD	n
Light-bellied Brent Goose	51	36	17	66	43	11
Grey Heron	1	2	10	1	2	6
Oystercatcher	74	15	17	92	35	11
Grey Plover	7	9	11	15	15	9
Dunlin	69	107	17	95	128	11
Bar-tailed Godwit	66	23	17	82	35	11
Curlew	14	13	16	20	15	11
Greenshank	1	1	10	3	2	11
Redshank	80	27	17	100	39	11
Turnstone	9	7	17	10	8	11
Black-headed Gull	119	141	17	111	117	11
Common Gull	56	85	17	49	37	11
Herring Gull	17	10	17	41	37	11
Great Black-backed Gull	1	2	5	10	7	11
Hooded Crow	12	5	17	15	9	11

Additional species (recorded on less than 50% of the counts): Red-breasted Merganser, Great Northern Diver, Great Crested Grebe, Cormorant, Knot, Sanderling, Whimbrel, Mediterranean Gull, Lesser Black-backed Gull and Rock Pipit.

Table 7.2 – Mean percentages on the tideline and feeding.

Species	Tideline %		Feeding %		n
	Mean	SD	Mean	SD	n
Light-bellied Brent Goose	100%	1%	74%	23%	12
Oystercatcher	62%	13%	77%	6%	12
Dunlin	44%	27%	85%	30%	9
Bar-tailed Godwit	86%	8%	92%	10%	12
Curlew	87%	13%	90%	10%	6
Redshank	58%	17%	96%	4%	12
Turnstone	39%	28%	78%	32%	5
Black-headed Gull	73%	27%	67%	26%	12
Common Gull	77%	30%	50%	31%	9
Herring Gull	97%	5%	33%	13%	8
Hooded Crow	60%	19%	70%	18%	8

Only species with four or more qualifying counts (i.e., total count > 9) included. Data from sector OY1 not included.

Table 7.3 – Mean counts and percentages of birds on trestles.

Species	On trestles counts			On trestles %		
	Mean	SD	n	Mean	SD	n
Light-bellied Brent Goose	6.4	5.6	12	15%	15%	12
Red-breasted Merganser	0.0	0.0	5			0
Cormorant	0.5	0.6	4			0
Grey Heron	1.0	1.0	7			0
Oystercatcher	38	12	12	49%	12%	12
Grey Plover	0.0	0.0	6	0%	0%	3
Dunlin	0.2	0.6	12	1%	2%	9
Bar-tailed Godwit	0.2	0.6	12	0%	1%	12
Curlew	0.5	0.7	12	1%	2%	6
Greenshank	0.2	0.4	5			0
Redshank	0.8	0.9	12	1%	1%	12
Turnstone	3.3	6.4	12	33%	27%	5
Black-headed Gull	3.6	4.5	12	6%	6%	12
Common Gull	3.6	5.1	12	8%	10%	9
Herring Gull	5.5	5.0	12	34%	20%	8
Hooded Crow	7.8	4.9	12	70%	15%	8

Only species with four or more non-zero counts are included in the *On trestles counts* columns and only species with four or more qualifying counts (i.e., total count > 9) are included *On trestles %* columns.
Additional species recorded on trestles were Great Black-backed Gull and Rock Pipit. Data from sector OY1 not included.

Assemblage analyses

7.5 We carried out exploratory analyses to identify patterns of assemblage variation using indirect gradient analyses. We then tested the hypothesis that waterbird assemblage variation is affected by the presence of oyster trestles, using direct gradient analysis.

Methods

7.6 We used a combined dataset, with data for sectors OY2 and OY3 from the extensive study counts and S1-S7 from the intensive study counts. We grouped the count data into four groups: OY2/S1-S4 outside oyster trestle blocks; OY2/S1-S4 within trestle blocks; OY3/S5-S7 outside trestle blocks; and OY3/S5-S7 within trestle blocks. This division reflects the distinction between the main block of trestles in OY3/S5-S7, and the more open habitat with scattered blocks of trestles in OY2/S1-S4. We used data for each individual count, so our dataset comprised 68 samples (17 counts x 4 groups). However, the OY3/S5-S7 outside trestle blocks group had very low abundances of all species, and several counts with no species recorded. This was due to the small area of open habitat within these sectors. Inclusion of this group resulted in ordinations in which most of the variation was represented by differences between samples within this group. Therefore, we excluded this group from the final analyses, resulting in a final dataset of 51 samples.

7.7 We carried out two sets of analyses: one using all species and the other using only species that predominantly feed on intertidal invertebrates. The latter group included Oystercatcher, Grey Plover, Sanderling, Dunlin, Bar-tailed Godwit, Curlew, Greenshank, Redshank and Turnstone. The gull species were excluded because they feed in a range of habitats and are, therefore, not dependent on the benthic invertebrate fauna.

7.8 For all analyses, only species that occurred in three or more samples were included. All count data was log (x+1) transformed before the analyses.

7.9 The indirect gradient analyses were carried out by non-metric multidimensional scaling analysis (NMS). The direct gradient analyses were carried out using canonical correspondence analysis (CCA). We used the following categorical environmental variables: SECTOR, DAY (count day from 5th January = 1 to 7th March = 13), OYSTER (0 = outside trestles blocks; 1 = within trestle blocks) and TLratio (tideline length/exposed intertidal area). For further details of the analytical methods see paragraphs 6.18-6.22.

Results

7.10 The NMS and CCA of both datasets produced ordinations with very similar arrangements of the species and samples in the ordination space. Therefore, only the CCA results are presented and discussed here.

7.11 The final CCA models included OYSTER, SECTOR and DAY as explanatory variables (Table 7.4). These parameters all improved the fit of the model (as measured by the AIC) and explained a significant component of additional variation (as measured by the permutation test) when added to the model.

7.12 The species-environment correlations are high (Table 7.4) and, overall 50% of the assemblage variation is explained by the constrained axes in the species analysis and 55% in the intertidal invertebrate feeding species analysis. However, the proportion of variation explained by the first two axes of the ordination was relatively low reflecting the inclusion of the categorical variable DAY, which resulted in a large number of the large number of constrained axes.

7.13 The CCA triplots show similar patterns of assemblage variation in the all species and intertidal invertebrate feeding species analyses (Figure 7.1 and Figure 7.2). The counts from sector OY2 outside the trestle blocks are largely separated from the counts from within trestle blocks, and there is more assemblage variation in the former compared to the latter. There is also a broad separation between the two sectors in the counts from within the trestle blocks.

7.14 In order to more clearly examine the arrangement of species along the OYSTER vector, we repeated the CCAs with DAY and SECTOR as covariables. Axis 1, which represents the OYSTER vector, explains 17% of the variation in the all species analysis and 24% of the variation in the intertidal invertebrate feeding species analysis. The ordering of species along axis 1 is shown in

7.15 Table 7.5. Sanderling, Grey Plover, Great Black-backed Gull, Red-breasted Merganser, Bar-tailed Godwit and Dunlin are associated with counts outside the trestle blocks, while Greenshank, Oystercatcher, Turnstone, Cormorant, Grey Heron and Hooded Crow are associated with counts within the trestle blocks.

Table 7.4 - Summary of the final CCA models

		Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7	Axis 8
All species	Eigenvalues	0.088	0.068	0.055	0.038	0.029	0.014	0.013	0.010
	Variance explained	0.133	0.102	0.083	0.057	0.043	0.021	0.019	0.015
	Species-environment correlations	0.88	0.83	-.83	0.77	0.70	0.67	0.63	0.51
Intertidal invertebrate feeding species	Eigenvalues	0.124	0.074	0.043	0.031	0.015	0.004	0.002	0.001
	Variance explained	0.232	0.139	0.081	.058	0.028	0.008	0.004	0.002
	Species-environment correlations	0.88	0.76	0.72	0.73	0.58	0.37	0.30	0.33

Table 7.5 – Axis 1 scores in the partial CCA analyses with OYSTER as the constraining variable and DAY and SECTOR as covariables.

Species	All species	Intertidal invertebrate feeding species
Sanderling	-0.71	-0.64
Grey Plover	-0.60	-0.58
Great Black-backed Gull	-0.44	
Red-breasted Merganser	-0.40	
Bar-tailed Godwit	-0.36	-0.33
Dunlin	-0.29	-0.25
Common Gull	-0.12	
Black-headed Gull	-0.08	
Herring Gull	-0.01	
Curlew	0.01	0.02
Light-bellied Brent Goose	0.07	
Redshank	0.07	0.12
Greenshank	0.26	0.30
Oystercatcher	0.26	0.30
Turnstone	0.27	0.30
Cormorant	0.36	
Grey Heron	0.53	
Hooded Crow	0.54	

Species analyses

7.16 We tested the null hypothesis that bird distribution within our study areas was not affected by the presence of oyster trestles, so that the observed occurrence of birds within areas of oyster trestles was not significantly different from that predicted by the percentage of the available habitat occupied by the oyster trestles. We used the combined dataset for sectors OY2 and OY3 from the extensive study and S1-S7 from the intensive study. We used the same methodology as described previously for the analysis of species distributions in the extensive study (see paragraphs 6.30-6.35).

7.17 We also compared bird densities within and outside the trestle blocks in lateral zones relative to the tideline. We used the tideline maps to categorise each band with exposed intertidal habitat in each sector on each count according to its position relative to the tideline, with the band containing the tideline categorised as Zone 0, the band above this was categorised as Zone 1, and the band(s) above Zone 1 were categorised as Zone 2. Where the tideline crossed between bands within a sector, both bands were categorised as Zone 0. We then calculated the total area and the total count in each zone on each count, and used these to calculate the densities. For Black-headed Gull and Common Gull we excluded birds swimming and/or hawking in/over subtidal habitat below the tideline. We did not calculate densities for Grey Plover and Knot, as their numbers were too low for detailed analysis. We did not calculate densities for Light-bellied Brent Goose, as they mainly occurred as birds swimming in subtidal water below the tideline (see paragraph 7.20.

7.18 We used analysis of variance (ANOVA) to test for differences between densities within and outside the trestle blocks. We tested the datasets for homogeneity of variance, using Bartlett's Test, and transformed datasets, where required, or used the non-parametric Friedman's Test where we were unable to transform the data to meet the assumptions of the ANOVA test. We used repeated measures ANOVA, with TRESTLE and ZONE as fixed factors and COUNT as the random factor, to analyse densities of Oystercatcher and Redshank. For the other species, the numbers occurring in Zones 1 and 2 were too small to allow such analyses without violating the assumptions for normality and error variance required for such tests. For Bar-tailed Godwit, Curlew, Turnstone, Black-headed Gull, Common Gull and Herring Gull we carried out the ANOVA using data for Zone O, only, TRESTLE as the fixed factor and COUNT as the random factor. For Dunlin, we used Friedman's Test with TRESTLE as grouping factor and COUNT as the blocking factor. We used untransformed data for Black-headed Gull and Herring Gull, log (x+1) transformed data for Bar-tailed Godwit, Curlew, Redshank and Common Gull, and square-root transformed data for Oystercatcher and Turnstone.

Light-bellied Brent Goose

7.19 Light-bellied Brent Goose occurred in all the counts, with a mean total of 51 in sectors OY2 and OY3. This species favoured sector OY2, with a mean of 75% of each count in this sector. The geese typically fed in the upper shore zone of sector OY1 when the tideline was above the oyster trestle blocks. As the tide fell they moved to the tideline and then moved north along the tideline through sector OY2 before dispersing, with some flocks flying across to the northern side of the bay.

7.20 On every count all the birds were on the tideline. Most birds would typically be swimming parallel to the tideline in a depth of water such that the tops of the trestles were just emerging from the water. They would feed by dabbling in the water, and as they encountered trestles, part of the flock would climb onto the trestles and feed on the trestles before moving on. Across all the counts a mean of 83% (s.d. 19%) of birds on each count were either swimming or on trestles surrounded by water.

Analysis

7.21 On most counts, observed numbers within the oyster trestle blocks were broadly in line with predicted numbers (Figure 7.3). However, there was one outlier below the 1:1 line. This probably reflects the behavioural pattern described above: as flocks of birds move along the tideline there will be a large element of chance as to whether the birds are within trestle blocks at the precise moment that they are counted.

Oystercatcher

7.22 Oystercatcher occurred in all the counts, with a mean total of 74 in sectors OY2 and OY3. 62% of birds were on the tideline and 77% were feeding. The standard deviations of all these parameters were relatively low, indicating low variability in the species behaviour between counts.

7.23 On average around half the birds recorded on each count were on trestles. Birds on trestles were more likely to be roosting, compared to birds elsewhere: mean percentage feeding on trestles was 62% (s.d. 10%) compared to 87% (s.d. 9%) elsewhere (paired t-test, $t = 8.09$, $p < 0.001$, $n = 17$).

7.24 Birds regularly settled on trestles when they were still below the tideline as they were just becoming exposed (mean count in intensive study of 6.8, s.d. 6.4).

Analysis

7.25 In all counts, observed numbers within the oyster trestle blocks were higher than the predicted numbers (Figure 7.4).

7.26 In the intensive study dataset (Table 7.6), mean densities were around 2.5 times higher within the oyster trestle blocks ($F_{1,11} = 81.4$, $p < 0.001$), and 5-10 times higher in the lateral zone containing the tideline compared to the other zones ($F_{2,22} = 70.0$, $p < 0.001$). The data shows some indication that the relative decrease in densities in lateral zones above the tideline was lower within the trestle blocks than outside the trestle blocks, but the interaction between the trestle effect and the zone effect was not significant ($F_{2,22} = 70.0$, $p < 0.001$, $p = 0.117$).

Grey Plover

7.27 Grey Plover occurred on nine counts with a mean total of 7 in sectors OY2 and OY3 and 15 in the counts including OY1. Apart from account of 51 on 3rd March, the numbers recorded in the counts including OY1 when the species was present varied from 4-29.

7.28 This species showed a strong preference for the northern part of the study area. Across all the counts that included OY1, over 90% of birds occurred in OY1 and S1-S3 and over 50% occurred in OY1.

7.29 The numbers recorded were too small for detailed analysis. However, observations of Grey Plover flock behaviour before/after the counts provided some evidence of the nature of their response to the oyster trestle blocks. Flocks of 50-80 Grey Plover were recorded on several occasions in sectors CS2 and CS3 above the main oyster trestle block before or after the counts, when the intensive study area was covered by the tide (Table 7.7). On most of these occasions these flocks were not present during the count period. The exception was the count on 7th March when 51 were present outside the trestle blocks in OY1 and the southern part of OY2. On one occasion part of the flock that had been feeding above the main oyster trestle block were observed flying across the Cunnigar into the inner part of Dungarvan Harbour, as the tideline receded towards the oyster trestle blocks.

Knot

7.30 Knot only occurred on two counts with 155 in the second count on 1st February and 36 on 3rd March.

7.31 The numbers recorded were too small for detailed analysis. However, observations of Knot flock behaviour before/after the counts provided some evidence of the nature of their response to the oyster trestle blocks. Flocks of 60-250 Knot were recorded on several occasions in sectors CS2 and CS3 above the main oyster trestle block before or after the counts, when the intensive study area was covered by the tide (

7.32 Table 7.8). On each occasion these flocks were not present during the count period.

Dunlin

7.33 Dunlin occurred on all the counts with a mean total of 69 in sectors OY2 and OY3. However, numbers were very variable and ranged from 6-382. 44% of birds were on the tideline and 85% of birds were feeding.

7.34 Dunlin typically occurred in scattered small groups across the study area. However, when large flocks were present they occurred in the open area in front of the trestle blocks in Sector 3.

7.35 Large Dunlin flocks were recorded on several occasions in sectors CS2 and CS3 above the main oyster trestle block before or after the counts, when the intensive study area was covered by the tide (Table 7.9). On each occasion these flocks were not present during the count period, and on one occasion part of the flock were observed flying across the Cunnigar into the inner part of Dungarvan Harbour, as the tideline receded towards the oyster trestle blocks.

Analysis

7.36 When large flocks were not present and predicted numbers were low (< 50), observed numbers within the oyster trestle blocks were similar to predicted numbers (Figure 7.5). However, on the three counts when higher numbers were present, observed numbers within the oyster trestle blocks were much lower than the predicted numbers.

7.37 In the intensive study, mean densities were over ten times higher in the lateral zone containing the tideline, compared to zones above the tideline and, in this zone, were around five times higher outside the trestle blocks compared to within the trestle blocks (Table 7.6). However, differences in densities between areas within and outside trestle blocks in the lateral zone containing the tideline were not significant due to the high variability in densities between counts (Friedman's χ^2 = 0.091, p-value = 0.763).

Bar-tailed Godwit

7.38 Bar-tailed Godwits occurred on all the counts with a mean total of 66 in sectors OY2 and OY3. 86% of birds were on the tideline and 92% were feeding.

7.39 Bar-tailed Godwits typically occurred in small groups scattered across the study area, and did not show obvious preferences for any particular area.

Analysis

7.40 In 14 of the 17 counts, observed numbers within the oyster trestle blocks were lower than the predicted numbers (Figure 7.6).

7.41 In the intensive study, mean densities were much higher in the lateral zone containing the tideline, compared to zones above the tideline and, in this zone, were around twice as high outside the trestle blocks compared to within the trestle blocks (Table 7.6) and this difference was significant ($F_{1,11}$ = 9.79, p = 0.001).

Curlew

7.42 Curlew occurred on all but one of the counts with a mean total of 14 in sectors OY2 and OY3. 87% of birds were on the tideline and 90% of birds were feeding.

7.43 Curlew typically occurred as scattered individuals or small groups across the study area, and did not show obvious preferences for any particular area.

Analysis

7.44 Across all qualifying counts, observed numbers within the oyster trestle blocks were broadly in line with predicted numbers (Figure 7.7).

7.45 In the intensive study, mean densities were over hundred times higher in the lateral zone containing the tideline, compared to zones above the tideline and, in this zone, were similar outside the trestle blocks compared to within the trestle blocks (Table 7.6; $F_{1,11}$ = 0.158, p = 0.698).

Redshank

7.46 Redshank occurred on all the counts with a mean total of 80 in sectors OY2 and OY3. 58% of birds were on the tideline and 96% of birds were feeding.

7.47 Redshank typically occurred as scattered individuals or small groups across the study area, but numbers were usually highest in the main oyster trestle block (sector OY3).

Analysis

7.48 Apart from one count, observed numbers within the oyster trestle blocks were consistently slightly higher than the predicted numbers (Figure 7.8).

7.49 In the intensive study, mean densities were over five times higher in the lateral zone containing the tideline, compared to zones above the tideline, and were around twice as high within the trestle blocks compared to outside the trestle blocks (Table 7.6), and these differences were significant (Trestle effect, $F_{1,11}$ = 25.5, p < 0.001; Zone effect, $F_{2,22}$ = 47.4, p < 0.001). There was also a significant interaction between the trestle effect and the lateral zone ($F_{2,22}$ = 3.91, p = 0.035) but this did not reflect a consistent difference in the decrease in densities in lateral zones above the tideline between areas within the trestle blocks and outside the trestle blocks.

Turnstone

7.50 Turnstone occurred on all the counts with a mean total of nine in sectors OY2 and OY3. 39% of birds were on the tideline and 78% were feeding.

7.51 Around 75% of the birds recorded across all the counts were within the main block of trestles in sector OY3.

7.52 On average around one-third of the birds recorded on each count were on trestles. Across all the counts, 33% of the birds on the trestles were feeding compared to 98% of birds not on trestles.

Analysis

7.53 On all of the seven qualifying counts, observed numbers within the oyster trestle blocks were higher than the predicted numbers (Figure 7.9).

7.54 In the intensive study, mean densities were over five times higher in the lateral zone containing the tideline, compared to zones above the tideline, and were around twice as high within the trestle blocks compared to outside the trestle blocks (Table 7.6). In the lateral zone containing the tideline the difference in densities between areas within and outside trestle blocks was significant ($F_{1,11}$ = 15.9, p = 0.002).

Black-headed Gull

7.55 Black-headed Gull occurred on all the counts with a mean total of 119 in sectors OY2 and OY3. However, numbers were very variable and ranged from 76-415. 73% of birds were on the tideline and 67% of birds were feeding.

7.56 Black-headed Gulls occurred throughout the study area. On some counts, sizeable flocks of roosting birds occurred outside the trestle blocks in sector OY2 (particularly in S3 and S4), while numbers of roosting birds in the main block of trestles in sector OY3 were always low.

7.57 Black-headed Gulls mainly fed on exposed sediments, but on some counts some birds were also recorded feeding while swimming and/or hawking in/over shallow water below the tideline. Few birds occurred on trestles.

Analysis

7.58 In 16 of the 17 counts, observed numbers within the oyster trestle blocks were lower than the predicted numbers (Figure 7.10) although the difference was usually small. However, when the analysis was restricted to birds on the tideline, observed numbers were almost exactly the same as predicted numbers (Figure 7.11).

7.59 In the intensive study, mean densities were much higher in the lateral zone containing the tideline, compared to zones above the tideline, and were similar within the trestle blocks compared to outside the trestle blocks (Table 7.6). In the lateral zone containing the tideline, there was no difference in densities between areas within and outside trestle blocks ($F_{1,11}$ = 0.1, p = 0.983).

Common Gull

7.60 Common Gull occurred on all the counts with a mean total of 56 in sectors OY2 and OY3. However, numbers were very variable and ranged from 2-357. 77% of birds were on the tideline and 50% of birds were feeding.

7.61 Common Gulls occurred throughout the study area but higher numbers generally occurred in sector OY2 compared to OY3.

7.62 Common Gulls mainly fed on exposed sediments, but on some counts some birds were also recorded feeding while swimming and/or hawking in/over shallow water below the tideline. Few birds occurred on trestles.

Analysis

7.63 In 12 of the 13 qualifying counts, observed numbers within the oyster trestle blocks were lower than the predicted numbers (Figure 7.12).

7.64 In the intensive study, mean densities were much higher in the lateral zone containing the tideline, compared to zones above the tideline, and were around twice as high outside the trestle blocks compared to within the trestle blocks (Table 7.6). However, in the lateral zone containing the tideline, the difference in densities between areas within and outside trestle blocks was not significant ($F_{1,11}$ = 3.58, p = 0.085).

Herring Gull

7.65 Herring Gulls occurred on all the counts with a mean total of 17 in sectors OY2 and OY3. 97% of birds were on the tideline and 33% of birds were feeding.

7.66 Herring Gulls occurred throughout the study area. In some of the counts that included sector OY1, large flocks were recorded in OY1.

7.67 Unlike Black-headed and Common Gulls, Herring Gulls were not recorded swimming or hawking in/over shallow water below the tideline. On average around one-third of the birds recorded on each count were on trestles.

Analysis

7.68 In 10 of the 13 qualifying counts, observed numbers within the oyster trestle blocks were lower than the predicted numbers (Figure 7.13) although the difference was usually small.

7.69 In the intensive study, nearly all birds occurred in the lateral zone containing the tideline, compared to zones above the tideline (Table 7.6). Within this zone, mean densities were around 1.25 times as high outside the trestle blocks compared to within the trestle blocks but this difference was not significant ($F_{1,11}$ = 0.036, p = 0.852).

Table 7.6 – Bird densities (number per 10 ha) in lateral zones relative to the tideline.

Position	Lateral zone 0				Lateral zone 1				Lateral zone 2			
Trestles	Outside		Within		Outside		Within		Outside		Within	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Oystercatcher	**15.4**	15.6	**38.7**	13.4	**1.5**	1.7	**4.9**	3.3	**0.8**	1.2	**7.0**	5.2
Dunlin	**54.4**	136.3	**11.8**	12.0	**4.4**	8.4	**1.3**	1.5	**2.7**	6.8	**0.7**	1.6
Bar-tailed Godwit	**5.8**	2.8	**2.3**	1.4	**0.2**	0.5	**0.2**	0.1	**0.0**	0.1	**0.0**	0.1
Curlew	**8.2**	14.0	**7.1**	6.5	**0.1**	0.2	**0.7**	1.1	**0.0**	0.0	**0.1**	0.5
Redshank	**17.0**	13.0	**38.4**	20.4	**3.4**	4.9	**7.9**	5.8	**2.3**	4.1	**3.8**	3.8
Turnstone	**0.9**	1.4	**5.3**	4.0	**0.1**	0.2	**1.0**	0.9	**0.0**	0.0	**1.6**	3.2
Black-headed Gull	**44.2**	52.4	**43.8**	70.3	**0.6**	1.6	**3.7**	6.3	**1.3**	0.3	**0.9**	1.6
Common Gull	**43.0**	64.5	**19.7**	26.4	**1.3**	2.4	**0.6**	1.0	**1.7**	8.4	**1.8**	7.1
Herring Gull	**10.3**	12.2	**8.2**	7.9	**0.1**	0.2	**0.0**	0.0	**0.0**	0.0	**0.0**	0.0

Table 7.7 – Additional counts of Grey Plover.

Date	Total during count (including OY1)	Before/after count	Notes
22 January	9	50 before	Feeding across full width of sector CS3 while study area completely flooded. When the tideline receded into the shoreline zone containing the oyster trestle blocks, at least part of the flock flew over the Cunnigar into the inner part of the harbour
03 February	20	57 before	Feeding across full width of sector CS3 at 09:15, while study area completely flooded
17 February	0	60 before	Feeding across northern part of CS2 and whole of CS3 at 08:20, while study area completed flooded
03 March	51	82 after	Feeding on advancing tide in Band A of S4 moving into CS2/CS3
07 March	4	62 after	34 feeding in upper part of CS1 and 28 feeding in upper part of CS2

Table 7.8 – Additional counts of Knot.

Date	Total during count (including OY1)	Before/after count	Notes
22 January	0	200 before	Feeding across full width of sector CS3 while study area completely flooded.
03 February	0	130 before	Feeding across full width of sector CS3 at 09:15, while study area completely flooded
17 February	0	85 before	Feeding across northern part of CS2 and whole of CS3 at 08:20, while study area completed flooded
03 March	36	60 after	Feeding on advancing tide in Band A of S4 moving into CS2/CS3
07 March	0	250 after	220 feeding in upper part of CS1 and 30 feeding in upper part of CS2

Table 7.9 – Additional counts of Dunlin.

Date	Total during count (including OY1)	Before/after count	Notes
22 January	15	1000 before	Feeding across full width of sector CS3 at while study area completely flooded
03 February	15	800 before	Feeding across full width of sector CS3 at 09:15, while study area completely flooded
17 February	382	1100 before	Feeding across northern part of CS2 and whole of CS3 at 08:20, while study area completed flooded
03 March	289	200 after	Feeding on advancing tide in Band A of S4 moving into CS2/CS3
07 March	7	700 after	640 feeding in upper part of CS1 and 60 feeding in upper part of CS2

Percentage of intertidal habitat shallowly flooded

7.70 The mean percentages of exposed intertidal habitat (i.e., above the tideline) shallowly flooded decreased from around 50% in the lateral zone containing the tideline to around 10% in Zone 3 (around 450 m from the tideline) (Figure 7.14).

7.71 The percentages of exposed intertidal habitat shallowly flooded within and outside the oyster trestle blocks were not significantly different, as the 95% confidence intervals of the mean differences per count included zero: Zone 0, 1.5% ± 10.3%; Zone 1, 7.9% ± 8.8%; Zone 2, -3.9% ± 6.4%; Zone 3, -3.6% ± 6.9%.

Disturbance

7.72 Oyster husbandry activity occurred on each count day. Workers usually arrived and departed in tractors, which accessed the beach at either the southern end of the Cunnigar or the slip at Moat. The first tractors usually arrived as soon as the trestles began to become exposed on the receding tide and the last tractors departed as the advancing tide covered the upper trestles. The number of tractors on the beach peaked around low tide, with maxima of 9-13 tractors on each of the count days.

7.73 Typically, a tractor would arrive on the beach with a trailer carrying a group of up to ten workers. The workers would be set down and would work along the trestle lines. Sometimes the tractor would move slowly along behind the workers. At other times, the tractor would be parked, or the tractor would drive off and leave the workers. Occasionally a dog would accompany a tractor or group of workers.

7.74 The main other potentially disturbing activity recorded was horse riding. This was recorded on all the count days. Pedestrian activity was high along the Cunnigar but few pedestrians ventured far out onto the sandflats.

7.75 During the intensive study counts, 15 incidences of disturbance impacts to waterbirds were observed, of which 11 were caused by tractors moving to/from or within the trestle bocks, one was caused by a dog following the tractors, two were caused by horses and one was caused by a Merlin (Table 7.10).

Table 7.10 – Disturbance impacts observed during the intensive study counts at Dungarvan Harbour.

Date	Disturbance caused by	Impact
05 Jan	1 tractor	Flushed birds most of which resettled within sector.
05 Jan	1 tractor	Flushed alot of birds, most of which resettled within sector but around 10-20 DN and BA flew north beyond S7
05 Jan	3 tractors	Tractors flushed a few RK, which all settled close to where flushed. 5 BH following tractor
20 Jan	1 tractor	Tractor drove across sector. Flushed c.10 RK & some gulls but they resettled within sector
24 Jan	4 tractors	Flushed a few OC, BA & RK all of which resettled within sector
24 Jan	1 tractor	Flushed 3 RK and 1 BH from open intertidal between trestle blocks
01 Feb	1 tractor	Flushed 2 RK. 5 BH following tractor for short distance.
01 Feb	Merlin	Flew low over trestles from where it flushed 2 OC, then began flying higher as it moved south.
17 Feb	1 tractor	Flushed 2 OC from intertidal outside trestles; these birds flew to S2
17 Feb	Dog following tractors	Dog following tractors, ran into edge of trestles and flushed 23 OC, 8 DN and 4 RK. These birds resettled in the intertidal habitat near the south-eastern edge of sector CS3 and then some moved in to the open intertidal (outside trestles) of S7A
17 Feb	1 tractor	Flushed 2 RK; birds resettled nearby
23 Feb	2 horses	Flushed flock of roosting gulls
07 Mar	3 tractors	Flushed PB from tideline in S4D. These birds resettled on the sea in S4E
07 Mar	1 tractor	Appeared to flush PB flock from intertidal at southern end of OY1
07 Mar	2 horses	Rode out into water beyond tideline. Flushed PB flock which flew south and landed in the intertidal at the southern end of OY1

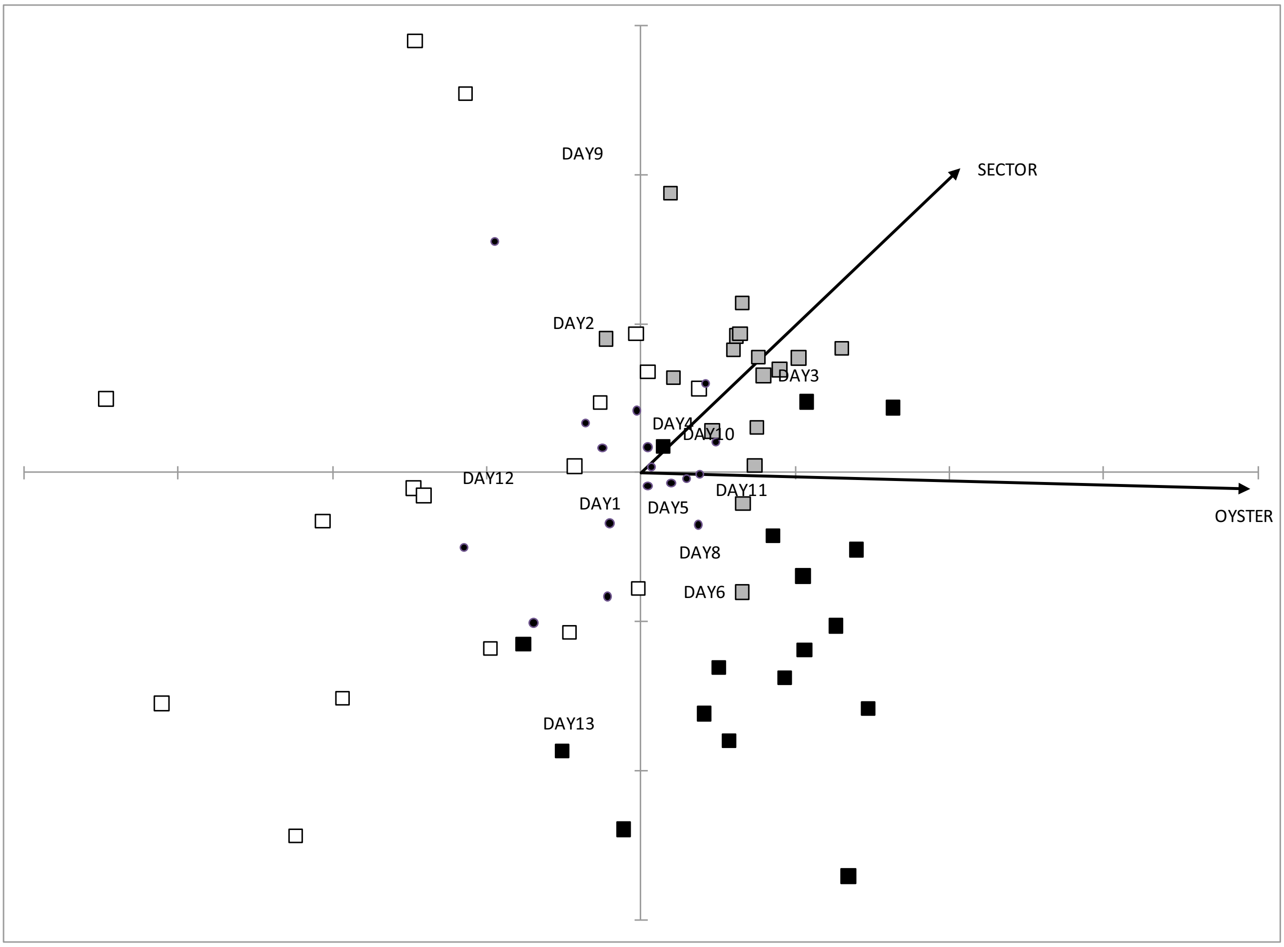


Figure 7.1 - CCA triplot of variation in the all species assemblage. Counts from sector OY2 outside oyster trestle blocks are shown as open squares, counts from sector OY2 inside oyster trestle blocks are shown as black squares and counts from sector OY2 inside oyster trestle blocks are shown as grey squares. Species positions in the ordination are shown as small circles.

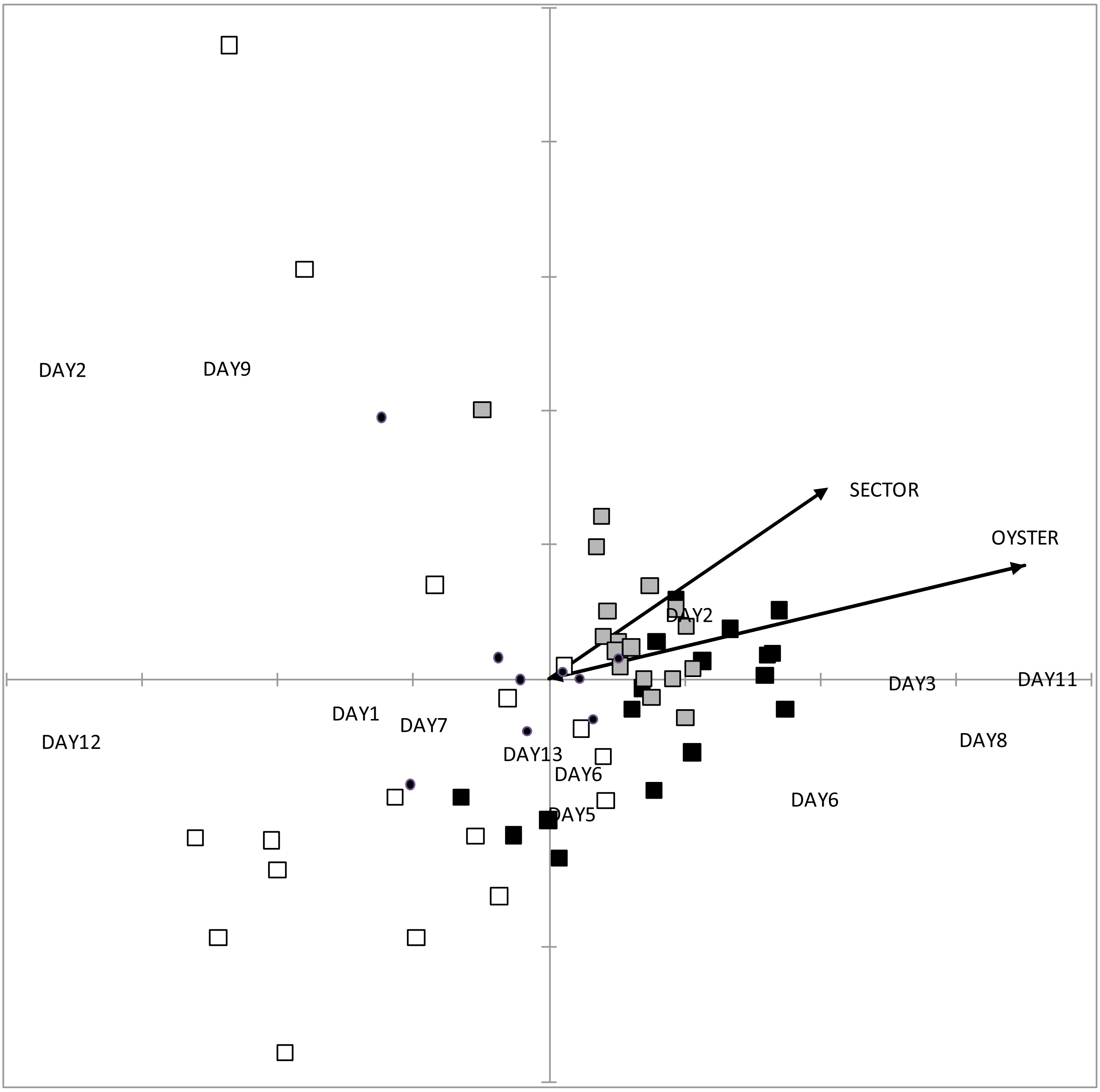


Figure 7.2 - CCA triplot of variation in the assemblage of intertidal invertebrate feeding waterbirds. Counts from sector OY2 outside oyster trestle blocks are shown as open squares, counts from sector OY2 inside oyster trestle blocks are shown as black squares and counts from sector OY2 inside oyster trestle blocks are shown as grey squares. Species positions in the ordination are shown as small circles.

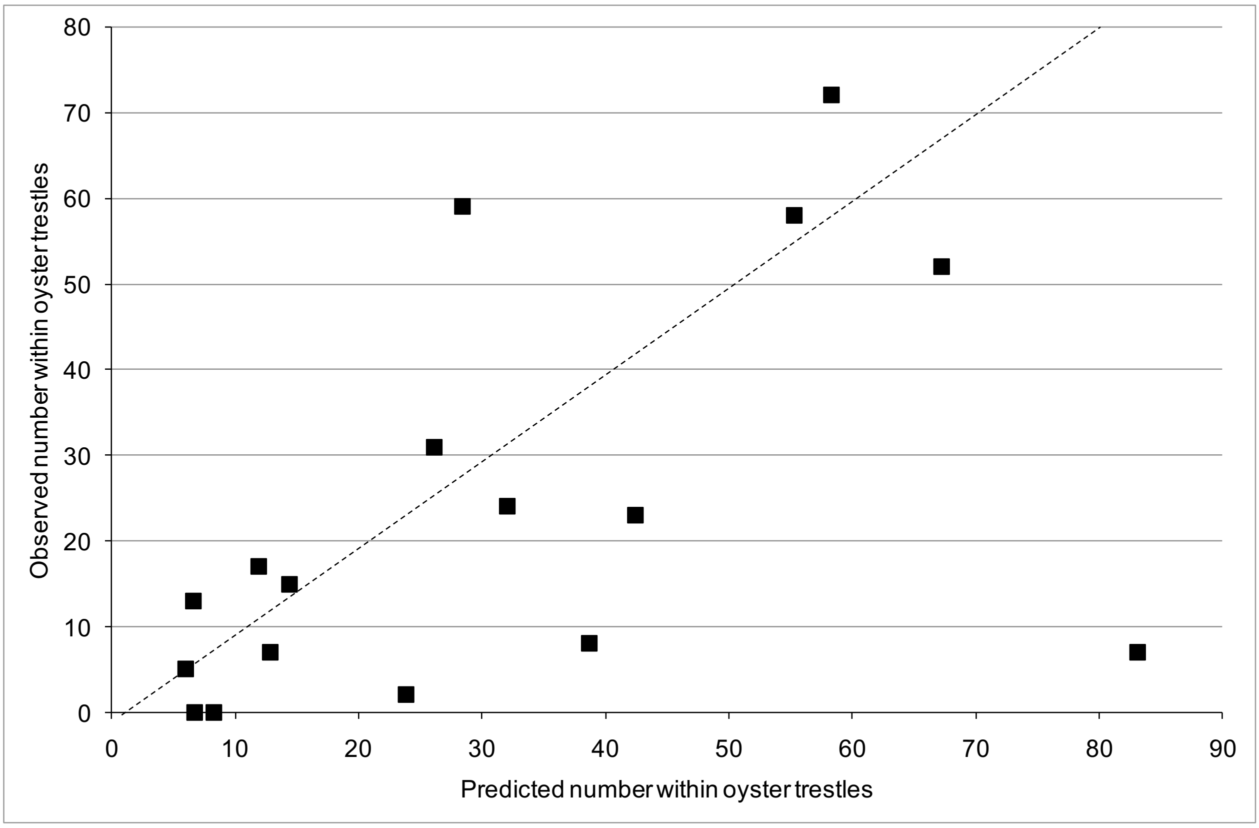


Figure 7.3 - Observed compared to predicted occurrence of Light-bellied Brent Goose within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour. Two data points with observed values of 0 have been displaced slightly for clarity.

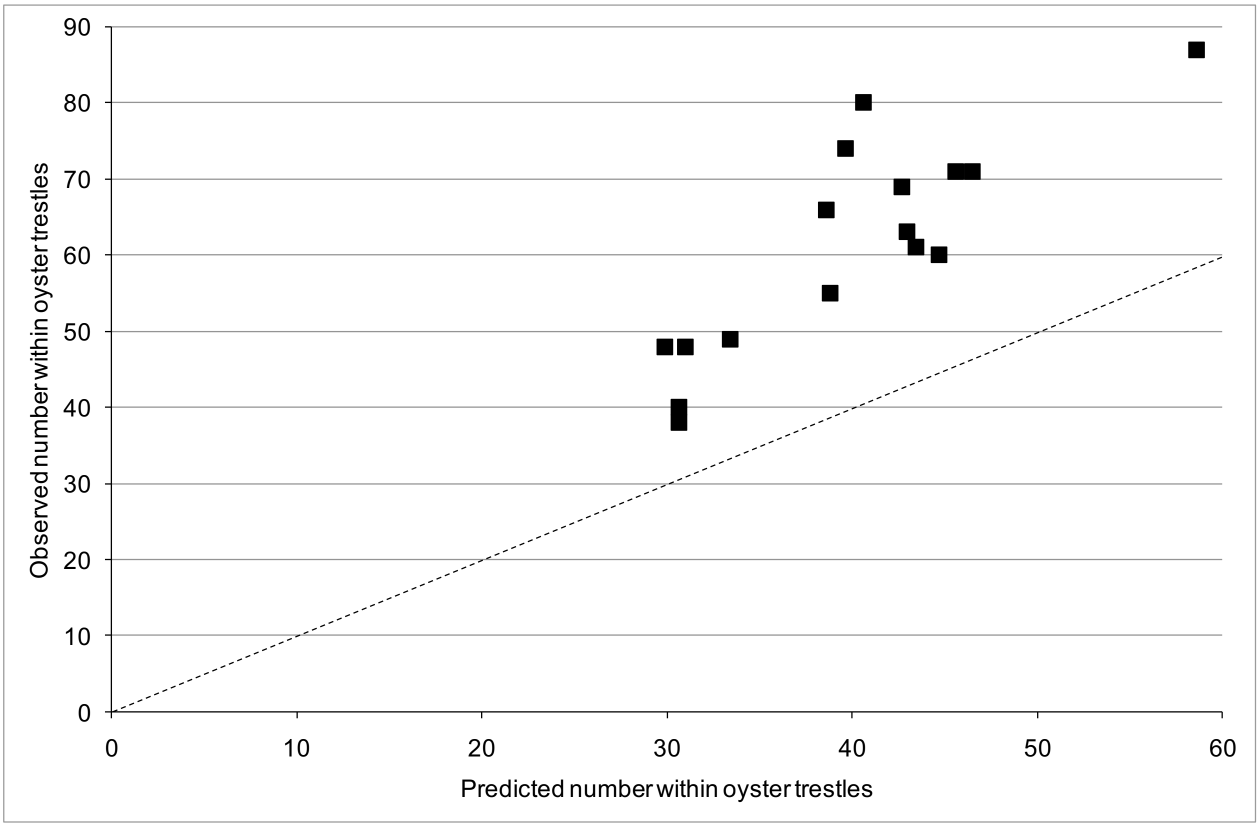


Figure 7.4 - Observed compared to predicted occurrence of Oystercatcher within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

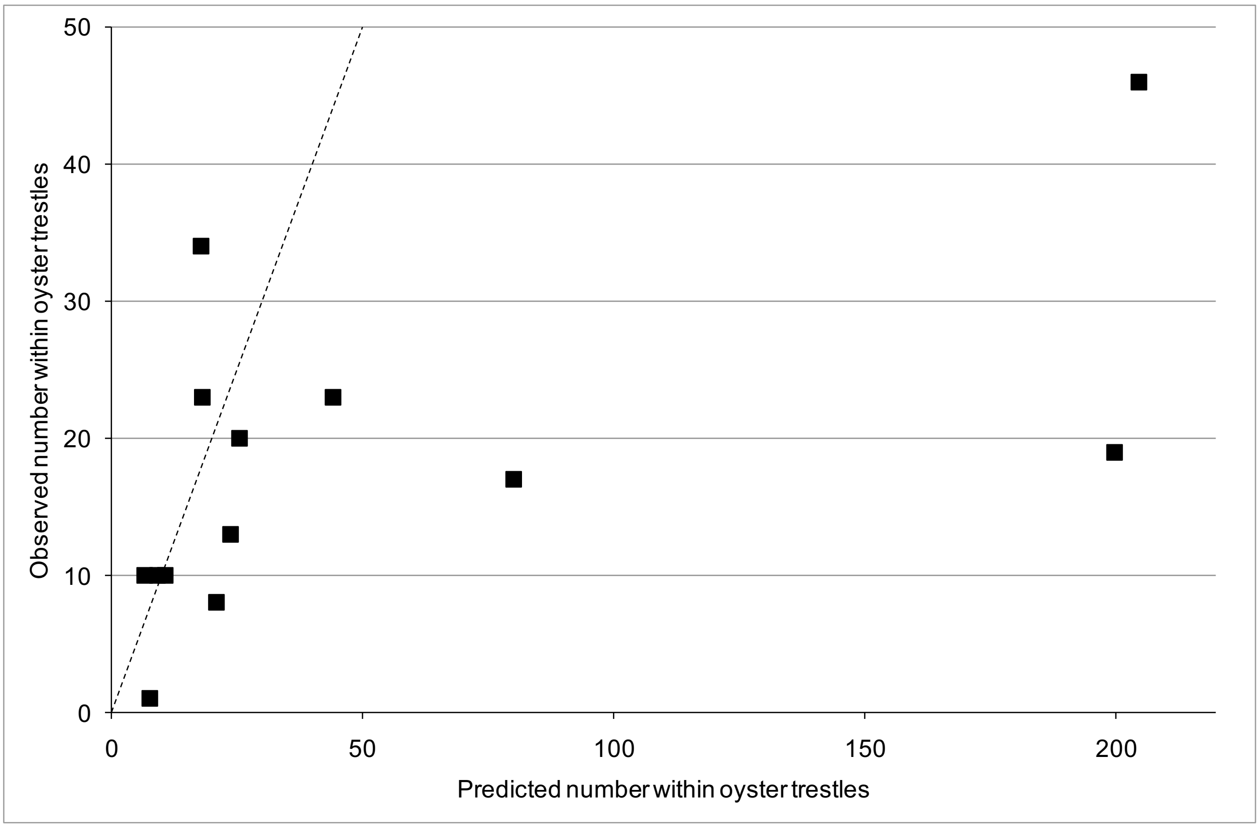


Figure 7.5 - Observed compared to predicted occurrence of Dunlin within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

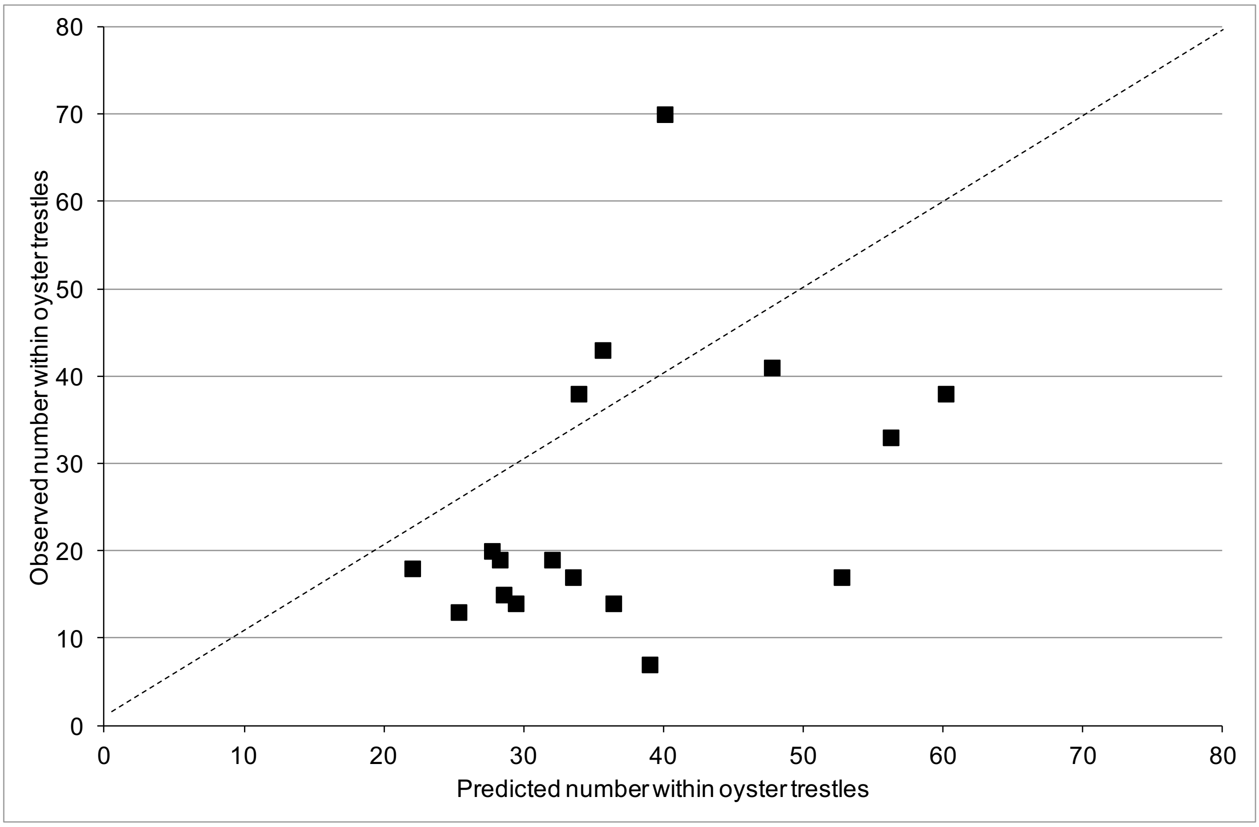


Figure 7.6 - Observed compared to predicted occurrence of Bar-tailed Godwit within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

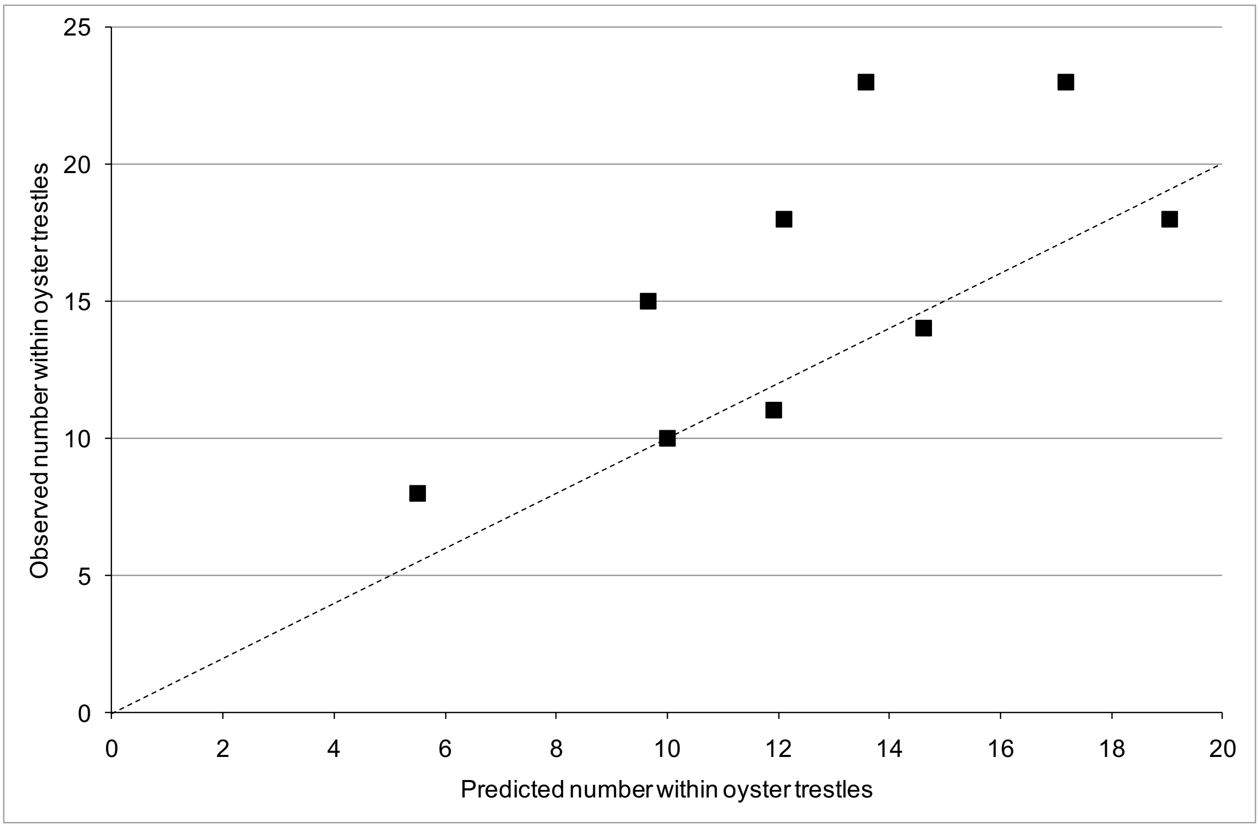


Figure 7.7 - Observed compared to predicted occurrence of Curlew within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

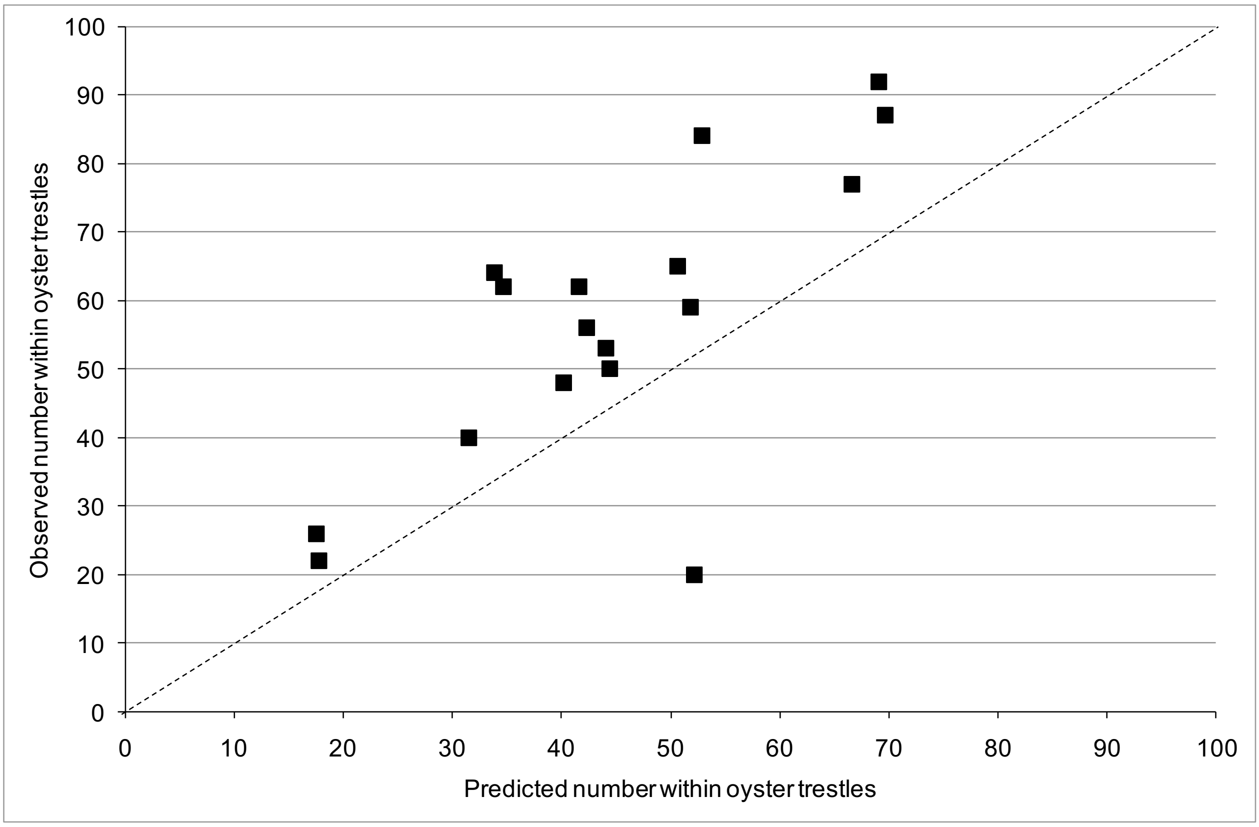


Figure 7.8 - Observed compared to predicted occurrence of Redshank within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

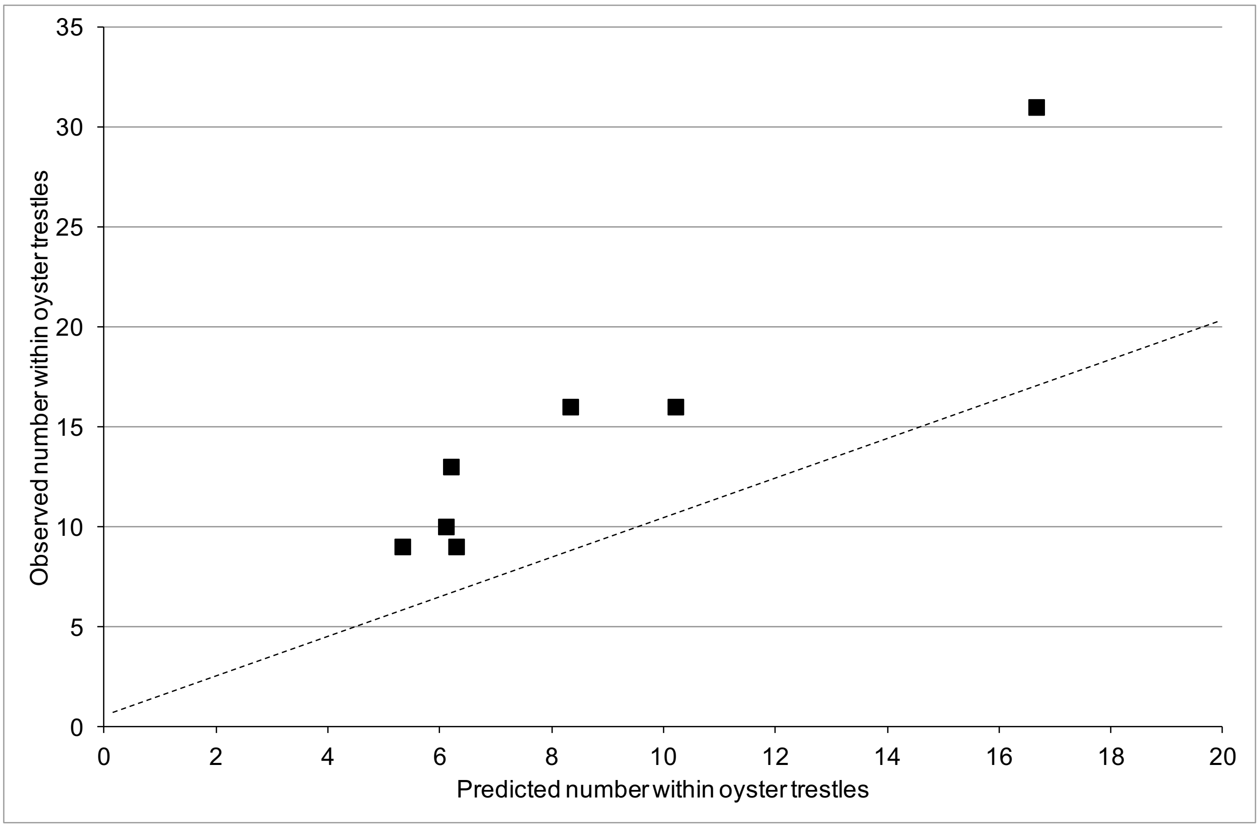


Figure 7.9 - Observed compared to predicted occurrence of Turnstone within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

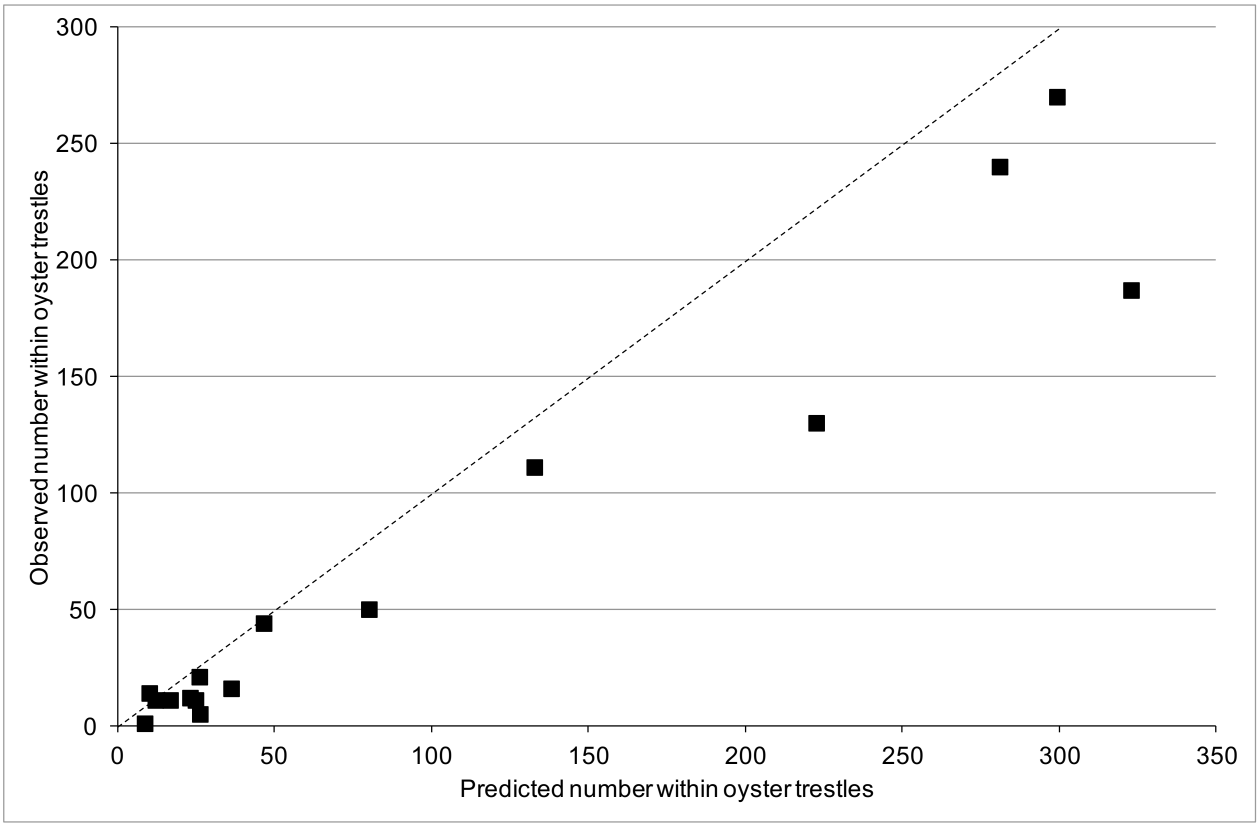


Figure 7.10 - Observed compared to predicted occurrence of Black-headed Gull within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

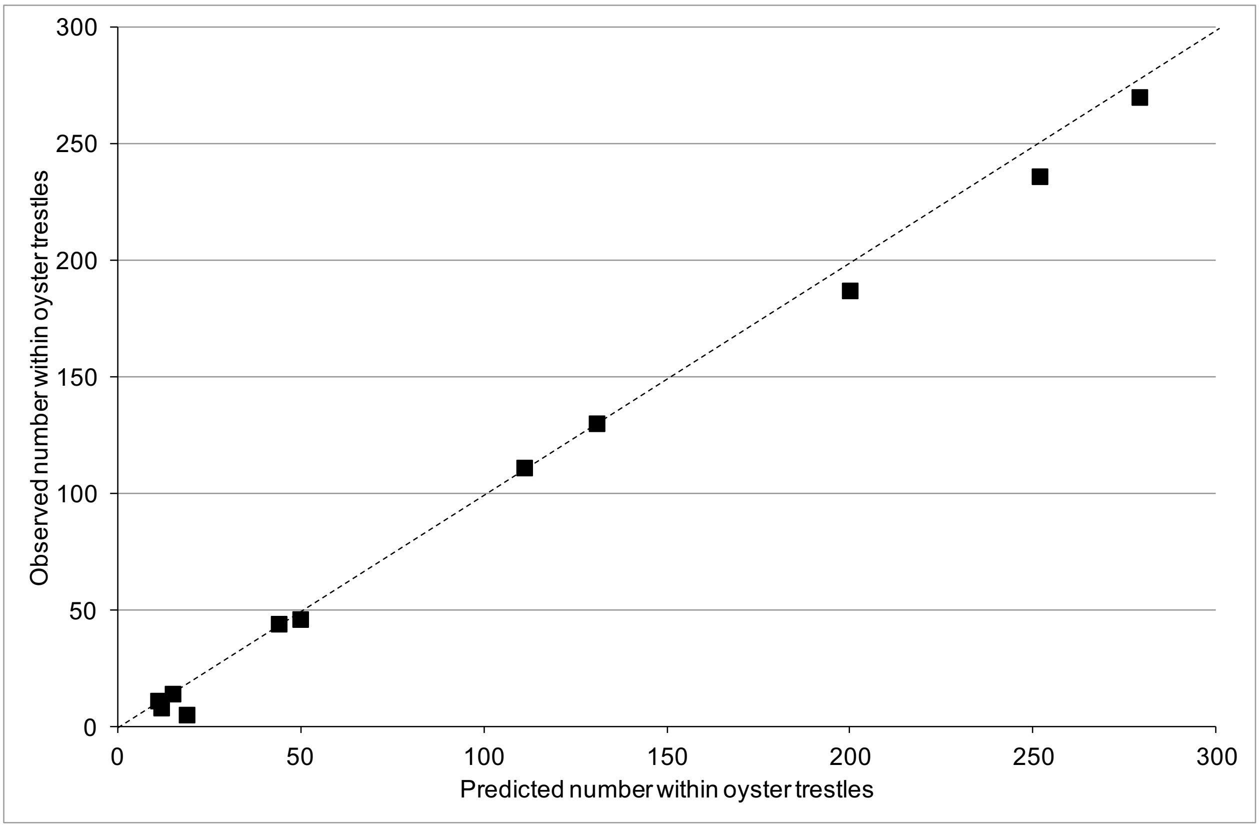


Figure 7.11 - Observed compared to predicted occurrence of Black-headed Gull on the tideline within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

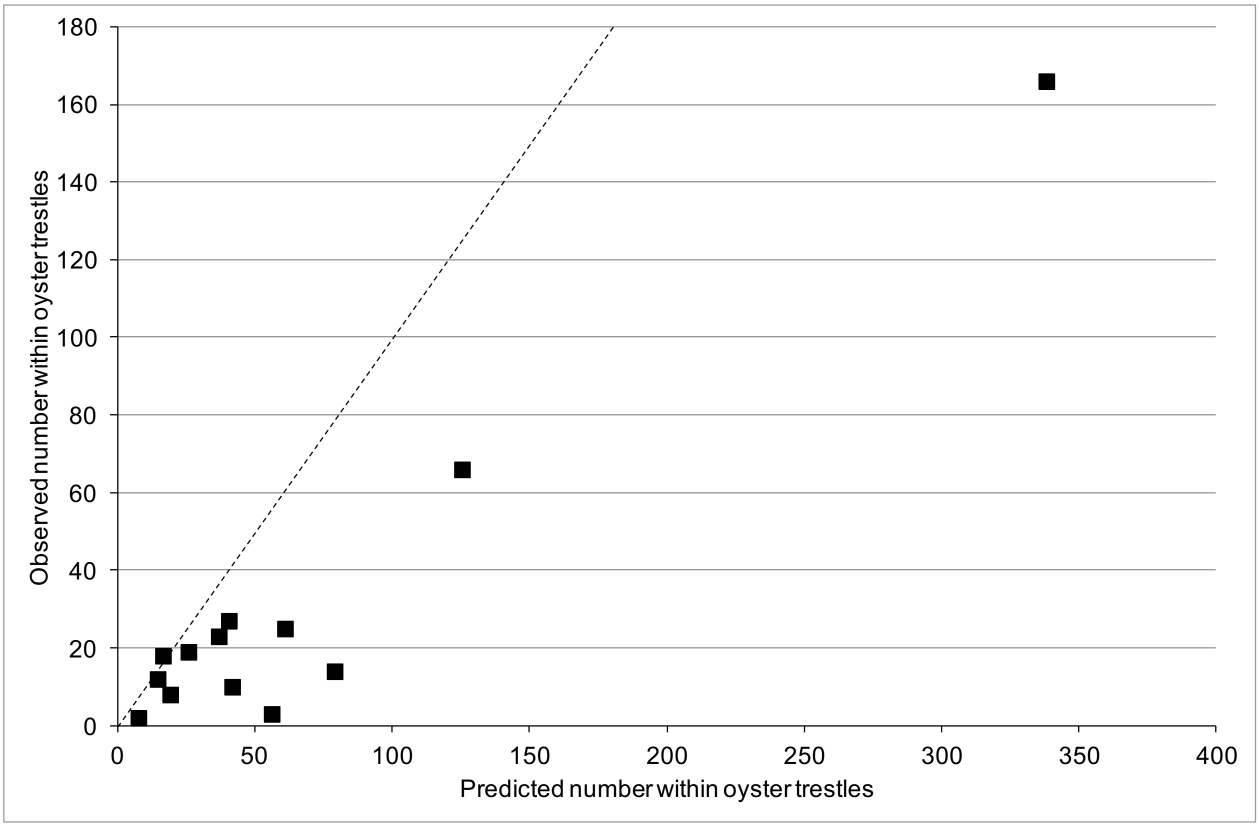


Figure 7.12 - Observed compared to predicted occurrence of Common Gull within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

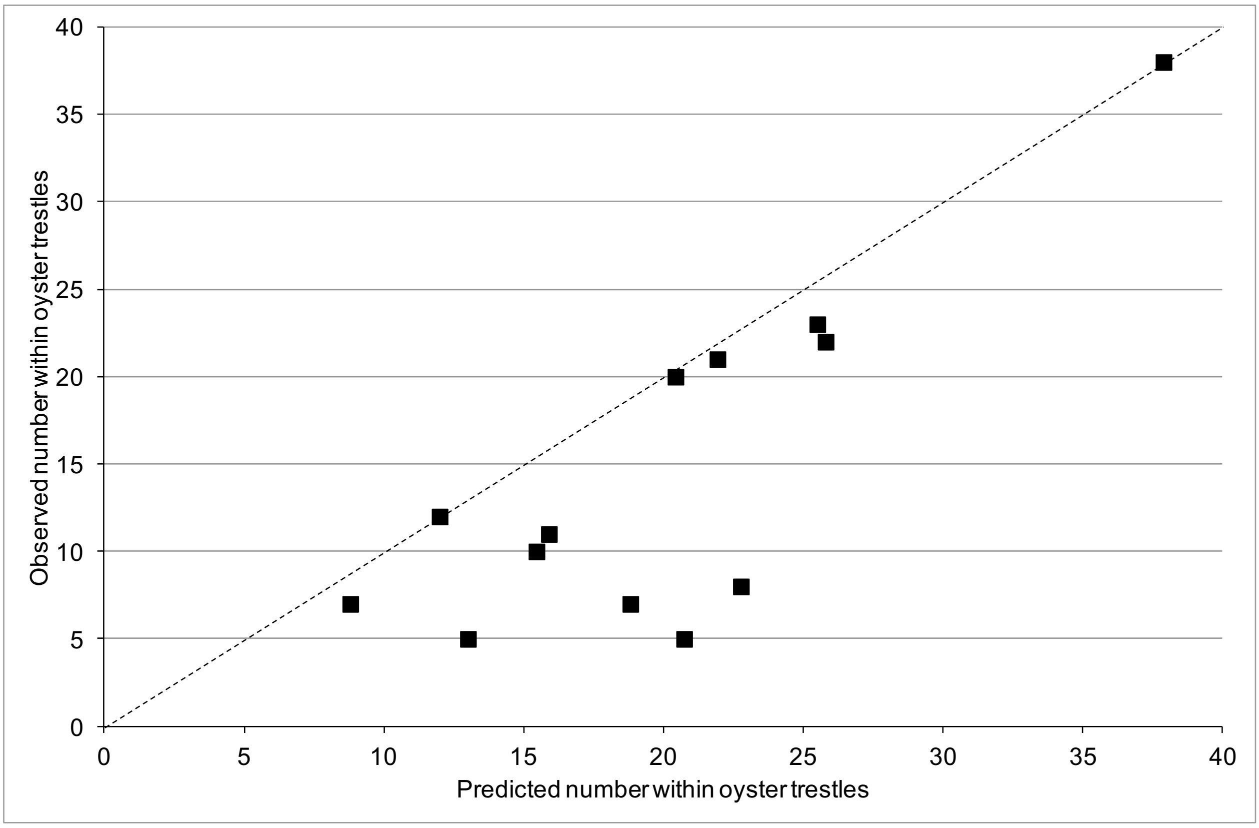


Figure 7.13 - Observed compared to predicted occurrence of Herring Gull within oyster trestle blocks using data in sectors OY2 and OY3 at Dungarvan Harbour.

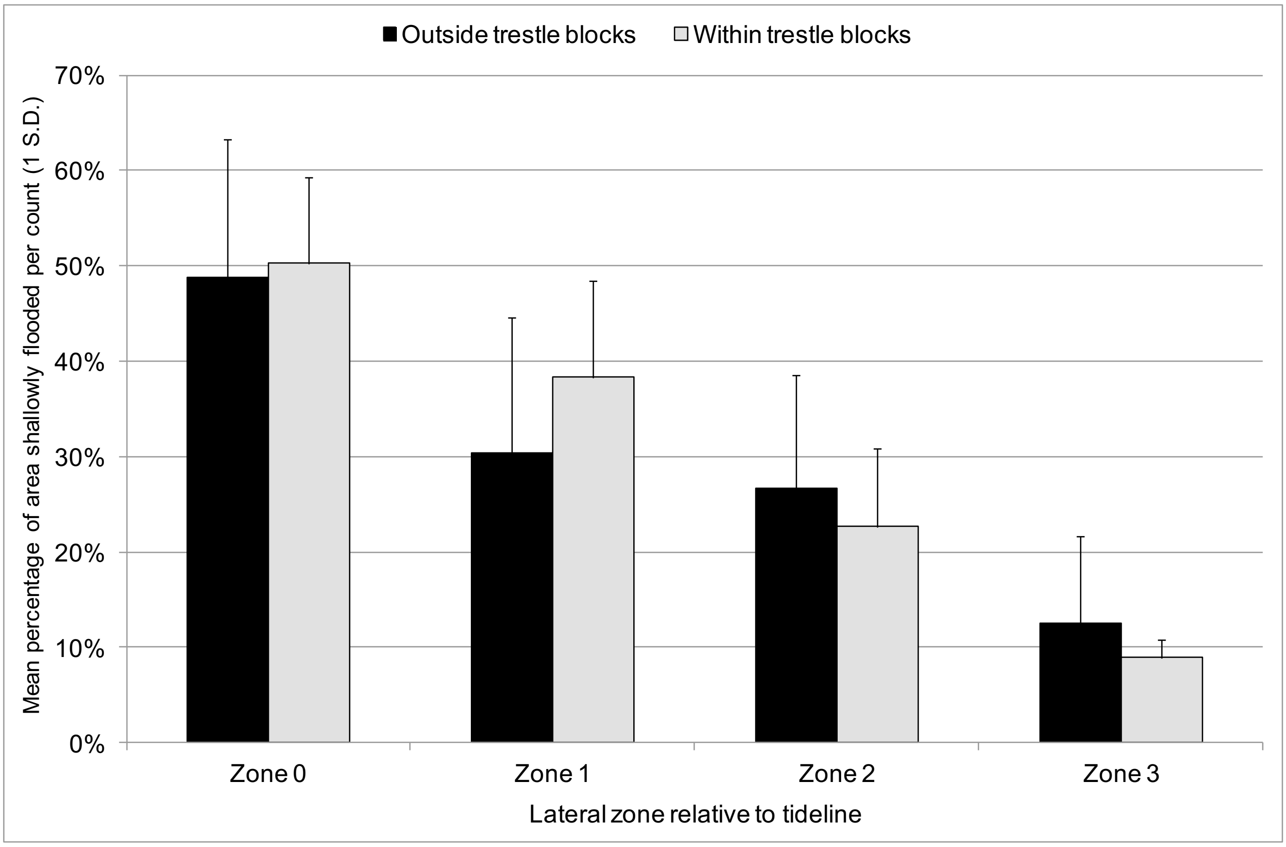


Figure 7.14 – Percentages of intertidal habitat shallowly flooded within and outside oyster trestle blocks in lateral zones relative to the tideline.

8. Discussion

Interpretation of results

8.1 We have used various analytical methods to investigate our data. These methods produced broadly similar results, but there were some specific differences between the apparent patterns of association with oyster trestle blocks indicated by the different analyses.

Assemblage analyses

8.2 The non-metric multidimensional scaling analyses (NMS) and the Canonical Correspondence Analyses (CCA) produced similar arrangements of samples in the ordination space. These similarities, as well as the high eigenvalues and species-environment correlations in the CCA analyses, indicate that the SITE and OYSTER factors explained a large degree of assemblage variation. These ordinations show that the assemblage of birds occurring within an oyster trestle area is significantly different to the assemblages outside such an area at the same site.

8.3 The correlation of species abundances with the ordination axes space in the NMS analysis of the all species dataset from the extensive study indicated negative associations with oyster trestle blocks for several species (Oystercatcher, Curlew and Redshank) which had neutral or positive associations with oyster trestle blocks in the other analyses. This is a reflection of the limitations of indirect gradient analyses: because the NMS analysis does not factor out differences between sites, interpretation of species association with trestles is confounded by differences between sites. The inclusion of the SITE factor in the CCA analyses allowed differences between sites to be included in the analyses.

8.4 The CCA analyses indicated very similar patterns of association with oyster trestle blocks to those indicated by the species analysis. The only significant discrepancy was the position of Bar-tailed Godwit in the partial CCA of assemblage variation in intertidal invertebrate feeding waterbirds in the extensive study. This probably reflects the fact that the CCA analyses did not factor in habitat availability (unlike the species analyses). Relatively large numbers of Bar-tailed Godwit occurred in the oyster trestle blocks at Dungarvan Harbour, reflecting the large population of the species and the large area of trestles at this site, and this may have biased the analysis.

8.5 The CCA analyses do provide information on the association with oyster trestle blocks for a number of species like Ringed Plover and Sanderling that were not covered or poorly covered by the species analyses, due to the limited data. However, the apparent association of these species with oyster trestle blocks indicated by the CCA analyses needs to be interpreted with caution as it may be biased by site-specific factors.

Species analyses

8.6 Our analyses of species distribution in relation to the presence of oyster trestle blocks are based on the assumption that the entire habitat in the count sectors included in the analyses are equally suitable for the species concerned. While we were careful to define study areas so that the sediment type was similar across the study area, there are likely to be other factors, such as variation in prey availability, which may cause variation in habitat suitability within study areas. There may also be geographical/behavioural factors, such as proximity to roost sites that affect species utilisation of different parts of the study areas. However, the very close 1:1 correlations between observed and predicted numbers for some species indicate that, at least for these species, our study area accurately represented the distribution of suitable habitat.

8.7 We carried out analyses at two spatial scales to address this issue. The all sectors analyses covered all, or most of the available habitat of similar sediment type to that occupied by the oyster trestle blocks. The larger scale of the area covered produced larger datasets for most species. However, these analyses have a higher risk of being biased by habitat differences and/or geographical/behavioural factors.

8.8 The close sectors analyses only included sectors adjacent to, or in close proximity to, oyster trestle blocks. These analyses are less likely to be biased by the above factors. However, they may miss large scale displacement potentially caused by the trestle blocks. For example, at Dungarvan Harbour the oyster trestle blocks are distributed throughout the lower shore zone of the southern side of the bay, and areas not currently occupied by trestles may have been occupied by trestles in the past. Therefore, if species show a behavioural response (avoidance) to the presence of trestles, and/or if oyster cultivation causes long-term habitat changes they may completely avoid the entire area included in the close sectors analysis.

8.9 Therefore, both the all sectors and close sectors analyses have advantages and disadvantages. These reflect the difficulties of attempting to study an impact after it has occurred. Obviously, the ideal study would be a Before-After-Control-Impact study over multiple sites. While such a study is unlikely to be practicable at the same scale as the study reported here, assessment work for future license applications may provide an opportunity for this kind of study.

Response to trestles

8.10 The responses of waterbird species to the presence of oyster trestle blocks, as indicated by the results of our analyses, are summarised in Table 9.1.

8.11 Species with variable responses could reflect differences between sites in the impact of the oyster trestle blocks on habitat suitability. In particular, the oyster trestles at Ballymacoda Bay were much “cleaner” than at the other sites and this could have affected the use of the oyster trestle blocks by species that frequently occurred on the trestles. Alternatively, differences between sites could be because at some sites the study area includes particularly favourable habitat outside the trestle blocks, which the species positively select so that a negative association with the area occupied by the trestle blocks would occur regardless of the presence of the trestles.

Species with neutral or positive responses

8.12 Oystercatcher, Redshank and Turnstone showed a neutral or positive response in all the analyses. Therefore, we consider that the overall response of Oystercatcher, Redshank and Turnstone to oyster trestles should be classified as neutral/positive, with a high degree of confidence.

8.13 Curlew showed a neutral response in most of the analyses. However, in the species analysis of the all sectors dataset, its response was variable with a negative response at Ballymacoda Bay and Waterford Harbour and a neutral or positive response at the other sites. While interpreting differences between sites in this dataset is dangerous given the generally low number of replicates for individual sites, the consistently negative response across eight counts (albeit on four days) at Ballymacoda Bay is notable. There is no obvious reason for the differences between sites, if these are real. In particular, Curlews do not frequently occur on trestles, so variation between sites in the condition of the trestles should not affect their response. Therefore, given the robust evidence of a neutral response from the intensive study, we consider that the overall response of Curlews to oyster trestles should be classified as neutral, but with only a moderate degree of confidence.

8.14 Greenshank showed a positive response in the assemblage analyses. As the assemblage analyses are less reliable than the species analyses (see paragraphs 8.4-8.5), the response of Greenshank to oyster trestles should be classified as neutral/positive, but with only a low degree of confidence.

Species with negative responses

Dunlin

8.15 Dunlin showed a negative response in all the analyses, except for the Observed/Expected analysis in the intensive study, where it showed a variable response. In the latter case, when large flocks observed numbers within the oyster trestle blocks were higher than the predicted numbers but on the three counts when higher numbers were present, observed numbers within the oyster trestle blocks were much lower than the predicted numbers. However, at other sites Dunlin showed a negative response even when predicted numbers were low. Therefore, we consider that the overall response of Dunlin to oyster trestles should be classified as negative, with a high degree of confidence.

8.16 The ratio between densities within and outside trestle blocks was highly variable between sites due to the fact that Dunlin were virtually absent from the trestle blocks at Ballymacoda Bay and Bannow Bay. In part this may reflect the fact that the relatively small extents of trestles at these sites were not large enough to support Dunlin: the area of intertidal habitat within trestle blocks at Ballymacoda Bay and Bannow Bay would support less than one Dunlin using the density of Dunlin in the intertidal at Dungarvan Harbour, while the tideline length within trestle blocks at Ballymacoda Bay would support less than three Dunlin using the density of Dunlin on the tideline at Dungarvan Harbour.

8.17 At Dungarvan Harbour, the mean densities in the extensive study were twice as high outside compared to within the trestle blocks on the tideline and around 7-8 times higher in the intertidal, while the mean density in the intensive study was nearly five times higher.

8.18 Because of the high variability in Dunlin numbers, there are high standard deviations for all these mean densities. More data would be required to obtain reliable estimates of the density reduction with oyster trestle blocks. At present, we consider that a conservative factor of 8 should be used to calculate the potential reduction in numbers using the affected area. Note that this may significantly overestimate the potential impact in areas used by small flocks.

Bar-tailed Godwit

8.19 Bar-tailed Godwit showed a negative response in all the analyses, except for the CCA analysis of the all species dataset in the extensive study, where it showed a neutral response. However, the latter is probably due to biases in the data analysis method (see paragraph 8.4). Therefore, we consider that the overall response of Bar-tailed Godwits to oyster trestles should be classified as negative, with a high degree of confidence.

8.20 The response appears to be stronger when large flocks are included in the dataset: the mean densities outside trestle blocks were around 5-9 times higher compared to within trestle blocks in the analyses including large flocks (see paragraphs 6.100-6.103), compared to around two times higher in the analyses where large flocks were not present (see paragraphs 6.100-6.103 and 7.41). At Dungarvan Harbour, this difference was due to the large flocks that occurred in the northern count sectors. Large flocks never occurred in the southern count sectors, even outside the trestle blocks, during our study and a similar restriction of large flocks to the northern count sectors is also evident in the data from the NPWS low tide counts in the winter of 2009/10. It is possible that the restriction of large flocks to the northern count sectors is due to a habitat factor other than the absence of oyster trestles. Alternatively, the absence of large flocks from the southern sectors may reflect the fact that trestle blocks occur throughout the lower intertidal zone in this area.

8.21 While there is a possible alternative explanation for the avoidance of trestle blocks by large flocks at Dungarvan Harbour, a similar pattern of avoidance is also evident at Ballymacoda Bay and Bannow Bay, and this avoidance pattern remained evident in the close sectors analyses at these sites. Therefore, we consider that the apparent avoidance of trestle blocks by large flocks should be treated as real. In predicting the impact of oyster trestle blocks a factor of 7 should be used to calculate the potential reduction in numbers using the affected area if large flocks (>~ 100 birds) use the area, and a factor of 2 if only small flocks (<~ 100 birds) use the area.

Other species

8.22 Grey Plover and Knot showed a negative response in all the analyses in which they were included, although there was only the limited data for these species in the species analyses of the extensive study and they were not included in the species analyses of the intensive study. However, observations of the flock behaviour of these species at Dungarvan Harbour provided strong evidence of avoidance of the oyster trestle blocks (see paragraphs 7.27-7.31). Therefore, we consider that the overall response of Grey Plover and Knot to oyster trestles should be classified as negative, with a high degree of confidence. As these species showed almost complete avoidance of the oyster trestle blocks, predictions of the impact of oyster trestle blocks should assume complete exclusion of these species from the affected area.

8.23 Shelduck, Ringed Plover, Lapwing, Sanderling, Black-tailed Godwit and Great Black-backed Gull showed a negative response in all the analyses in which they were included. However, these were mainly the assemblage analyses, which are less reliable than the species analyses (see paragraphs 8.4-8.5). For Ringed Plover, Sanderling and Black-tailed Godwit there are behavioural similarities with species where there is high degree of confidence about their negative response (see paragraph 8.23). However, given the limited data we consider that the overall response of Shelduck, Ringed Plover, Lapwing, Sanderling, Black-tailed Godwit and Great Black-backed Gull to oyster trestles should be classified as negative, with a low degree of confidence. Because of the limited data, predictions of the impact of oyster trestle blocks should assume complete exclusion of these species from the affected area, although this is likely to be a conservative assumption for at least some of these species.

Species with variable responses

8.24 Light-bellied Brent Goose showed a neutral response in the analyses of the intensive study. However, this response mainly reflected the distribution of geese swimming along the receding tideline as it passed through the trestle blocks. Therefore, this response does not indicate the impact of oyster trestle blocks on the suitability of intertidal habitat for this species. In the extensive study species analysis, it showed a variable response with observed numbers within the oyster trestle blocks broadly in line with predicted numbers at Dungarvan Harbour and Waterford Harbour but generally lower than the predicted numbers at Ballymacoda Bay and Bannow Bay. As this species frequently occurs on trestles, it is possible that these differences between sites in the management of the trestles could affect their suitability and usage. However interpreting differences between sites in this dataset is dangerous given the generally low number of replicates for individual sites.

8.25 Black-headed Gull and Common Gull showed neutral, variable and negative responses in different analyses. In the extensive study, observed numbers were similar to predicted numbers when predicted numbers were low (<~40-50) but were lower than predicted numbers when the latter were higher. In some, but not all, cases this pattern reflected the presence of large flocks feeding or roosting on the sandflats away from the tideline. However, in the intensive study observed numbers were lower than predicted numbers even when the latter were low. However, the reductions in densities in the intensive study were quite low (around 1.5 times for Black-headed Gull and two times for Common Gull).

8.26 Herring Gull showed a neutral response in the extensive study species analysis and the intensive study assemblage analysis but a negative response in the intensive study species analysis. However, in the latter the density outside the trestle blocks was only around 1.25 times higher than the densities inside.

8.27 Because these species show an apparently variable response, it is not possible to come up with a simple method for assessing the potential impact of oyster trestles on them. Light-bellied Brent Goose are an SCI species in a number of SPAs and are likely to be an issue in the Appropriate Assessment of intertidal oyster culture at a number of sites. Therefore further research may be required for this species. The gull species are not dependent on intertidal habitat and it is unlikely that intertidal oyster culture areas would occupy habitat used by 5% or more of their site populations (although this may not be evident from I-WeBS data which generally do not adequately count gull populations). Therefore, it is unlikely that detailed assessment will be required for these gull species.

Overview

8.28 The species that showed a neutral/positive response are all waders that tend to feed in small flocks (Turnstone) or as widely dispersed individuals/loose flocks (Oystercatcher, Curlew, Greenshank and Redshank). The species that showed a negative response are mainly species that tend to feed in large flocks of tightly packed individuals (Knot, Sanderling, Dunlin, Black-tailed Godwit and Bar-tailed Godwit, and to a lesser extent Ringed Plover). Furthermore, for the two species out of the latter group where we had good data, the negative response appears to be stronger when large flocks are involved. Folmer *et al*. (2010) found that Knot and Dunlin are more clustered than predicted by their food resources suggesting that they follow each other when selecting foraging patches, implying that visual contact between flock members is important. Therefore, the above suggests that the negative response to oyster trestle blocks may be a behavioural response by species where the oyster trestles interfere with their flocking behaviour by making it difficult for individuals in large flocks to remain in contact as they become dispersed across several lines of trestles. The division of species into these two groups does not correspond to differences in their diet.

8.29 In the only other replicated study of the effect of oyster trestles on waterbird distribution, Kelly *et al*. (1996), the statistically significant responses conformed to the above pattern: a negative response was reported for Western Sandpiper and Dunlin and a positive response was reported for Willet. The Western Sandpiper is a small calidrid that tends to feed in large tightly-packed flocks. Willet is a large wader that tends to feed as widely dispersed individuals/loose flocks. The responses reported by Hilgerloh *et al*. (1999) do not conform to this pattern. However, their study was not replicated, and the negative response they report for Oystercatcher (a species with a consistently neutral/positive response in our study) suggests that other factors may be confounding their results. The responses reported by Connolly and Colwell (2005) in their study of intertidal longline oyster culture also do not conform to the above pattern, but longlines appear to be less likely to interfere with visual contact between birds feeding at ground level (see photograph in Figure 2 of Connolly and Colwell, 2005).

8.30 The response of Grey Plovers in our study did not conform to the general pattern. Grey Plovers showed a strong negative response, but are a species that tends to feed as widely dispersed individuals/loose flocks. Grey Plovers have complex territorial behaviour (Townshend *et al*., 1984;

Wood, 1986) so it is possible that the oyster trestles interfere with this territorial behaviour. However, Curlew, which showed a neutral/positive response, also defends feeding territories.

8.31 It is also notable that the species that show a negative response to oyster trestles generally favour open mudflats or sandflats and usually do not occur in large numbers in mixed sediment or rocky shores. Therefore, selection of mixed sediment or rocky shore sites for intertidal oyster culture would be likely to reduce the potential impact on waterbirds, and would also simply the appropriate assessment requirements. We did not compare waterbird numbers within and outside oyster trestle blocks in mixed sediment or rocky shores and, it is possible that some species that showed a neutral/positive response in our study could show a negative response to oyster trestles on mixed sediment or rocky shores. However, mixed sediment/rocky shores generally do not hold large numbers of most waterbird species, with a few exceptions such as Oystercatcher (on mussel beds) and Turnstone.

8.32 A final consideration is that oyster trestles mainly occur in the lower zone of the intertidal in habitat which is not exposed on every low tide. Therefore, the impact of the avoidance of oyster trestle blocks by species with a negative response to the presence of trestles may need to be adjusted to reflect the proportion of low tides during which they are exposed.

Disturbance

8.33 Oyster husbandry activity occurred on most count days across our study sites indicating that, at least during our study period, it is likely to occur during most suitable tides.

8.34 Detectable disturbance impacts to birds were only observed occasionally and were usually only minor (birds which flushed but resettled nearby). Avoidance of the vicinity of husbandry activity would have been difficult to detect in the field due to the low density and dispersed distribution of waterbirds across the sandflats at low tide. However at Dungarvan Harbour, Oystercatchers, Dunlin, Bar-tailed Godwit and Redshank were frequently observed feeding close to (within 50-100 m) husbandry activity, while gulls often followed tractors.

8.35 Data from our intensive study could be used to investigate species responses to disturbance in more detail, by comparing species occurrence in sector-bands with husbandry activity to their occurrence in sector-bands without husbandry activity.

8.36 However, the effects (if any) of disturbance from husbandry activities are included in our analyses of species distribution and will, therefore, be reflected in our classification of species responses to oyster trestle blocks.

Table 8.1 – Summary of species response to the presence of oyster trestle blocks.

Study	Extensive study		Intensive study			Flock movements at Dungarvan Harbour
Analysis	Assemblage	Species[1]	Assemblage	Species		
Species	CCA	Observed/Expected	CCA	Observed/Expected	Densities[2]	
Light-bellied Brent Goose		Variable	Neutral	Neutral		
Shelduck	Negative	Unknown				
Wigeon		Unknown				
Red-breasted Merganser			Negative			
Cormorant			Positive			
Grey Heron			Positive			
Oystercatcher	Positive	Neutral	Positive	Positive	Positive	
Ringed Plover	Negative		Negative			
Grey Plover	Negative	(Negative)	Negative			Negative
Lapwing		(Negative)				
Knot	Negative	(Negative)	Negative			Negative
Sanderling	Negative		Negative			
Dunlin	Negative	Negative	Negative	Variable	(Negative)	Negative
Black-tailed Godwit	Negative	(Negative)				
Bar-tailed Godwit	Neutral	Negative	Neutral	Negative	Negative	
Curlew	Neutral	Variable	Neutral	Neutral	Neutral	
Greenshank	Positive		Positive			
Redshank	Positive	Neutral	Positive	Positive	Positive	
Turnstone	Positive	Positive	Positive	Positive	Positive	
Black-headed Gull		Variable	Neutral	Variable	(Negative)	

Study	Extensive study		Intensive study			Flock movements at Dungarvan Harbour
Analysis	Assemblage	Species[1]	Assemblage	Species		
Species	CCA	Observed/Expected	CCA	Observed/Expected	Densities[2]	
Common Gull		Variable	Neutral	Negative	(Negative)	
Lesser Black-backed Gull		Unknown				
Herring Gull		Neutral	Neutral	Negative	(Negative)	
Great Black-backed Gull		(Negative)	Negative			

Species responses indicated by the assemblage analyses have lower confidence than species responses indicated by the species analyses.

[1] Responses in parentheses are based on limited data; Unknown indicates that there was sufficient data to include the species in the analysis, but no conclusion could be drawn from the results of the analysis.

[2] Responses in parentheses indicate that the difference in densities was not statistically significant.

9. Predicting the impact of intertidal oyster culture

Introduction

9.1 The objective of this section is to provide a toolkit that can be used to assess the potential impact of intertidal oyster cultivation in the context of carrying out an Appropriate Assessment.

9.2 Because Appropriate Assessment is only concerned with predicting negative impacts, potential positive impacts of intertidal oyster culture are not covered in this section.

9.3 Species that primarily use subtidal habitat are not considered in this section, as our study was not designed to assess usage of subtidal habitat.

Species response to intertidal oyster cultivation

9.4 Species response to intertidal oyster cultivation, as evaluated from the results of our study, are summarised in Table 9.1.

9.5 Species with an unknown response are species that did not occur in our study sites, or for which our study did not produce sufficient data to assess their response. We have categorised their possible response based on knowledge of their behaviour and habitat preferences and, in some cases, similarity to species which we were able to evaluate.

Table 9.1 – Response of waterbird species to intertidal oyster cultivation.

Response	Species
Neutral/positive	Oystercatcher, Curlew, Redshank, *Greenshank*, Turnstone
Variable	Light-bellied Brent Goose, Black-headed Gull, Common Gull, Herring Gull
Negative	*Shelduck, Ringed Plover*, *Lapwing*, *Sanderling*, Dunlin, *Black-tailed Godwit*, Bar-tailed Godwit, *Great Black-backed Gull*
Exclusion	Grey Plover, Knot
Unknown (neutral/positive)	Little Egret and Grey Heron
Unknown (variable)	Lesser Black-backed Gull
Unknown (negative)	Wigeon, Teal, Mallard, Pintail, Shoveler and Golden Plover

Impact assessment methodology

Context

9.6 The following methodology has been developed to provide a consistent approach to the assessment of the potential impact of intertidal oyster cultivation in the context of Appropriate Assessment of aquaculture activities in coastal SPAs.

9.7 The methodology uses a displacement level of 5% as the threshold for significance: i.e., if oyster trestles are predicted to cause displacement of 5% or more of the site population of a SCI species, then the impact is considered to be significant. This criterion has been used in Appropriate Assessments in Castlemaine Harbour and Dundalk Bay (Marine Institute, 2011a, b) and has been accepted by NPWS in the context of those assessments. The rationale behind this criterion is discussed in those Appropriate Assessments.

9.8 The methodology uses the categorisation of species responses to oyster trestles derived in this study, and, therefore, applies to intertidal oyster cultivation in mud/sandflats. The methodology does not apply to intertidal oyster cultivation in mud/sandflats on mixed sediment/rocky shores (see paragraph 8.31). However, in coastal SPAs designated for waterbirds, mixed sediment/rocky shores will occupy relatively small proportions of the site and are unlikely to hold large proportions of the populations of most SCI species (apart from Turnstone and, possibly, Oystercatcher). Therefore, in most cases, development of intertidal oyster cultivation in such habitat is unlikely to cause displacement of 5% or more of the site population.

9.9 We have used the results of our study to derive multipliers to calculate reductions in numbers within oyster trestle blocks for Dunlin and Bar-tailed Godwit. These multipliers are based on robust data from the sites and time periods that we studied. However, it is possible that these multipliers may not apply in other sites/time periods. Therefore, a precautionary approach may be required in the assessment of these species.

9.10 Where oyster trestles occur on intertidal habitat that is not exposed on every low tide, the results of assessments made using the following methodology may need to be adjusted to reflect the proportion of low tides during which they are exposed (see paragraph 8.32).

9.11 The procedure is described in full below and a flow chart summarising the procedure is shown in Figure 9.1.

Procedure

9.12 Categorise the waterbird SCI species according to their potential response to intertidal oyster cultivation.

9.13 Species with a neutral/positive response can be excluded from further assessment and no impact can be determined for these species with the following confidence levels:

- High - Oystercatcher, Redshank and Turnstone
- Moderate – Curlew
- Low - Greenshank

9.14 For the other species, their spatial distribution within the site should be assessed to determine whether the intertidal oyster cultivation area(s) are within the area(s) they occupy. In sites where the assessment is being carried out on existing intertidal oyster cultivation, this assessment will have to consider whether the existing cultivation occupies habitat that would otherwise be suitable for the species, and which would fall within the species pattern of occurrence at the site.

9.15 If the intertidal oyster cultivation area(s) are clearly outside the area(s) occupied by the species, and areas that have the potential to be occupied by the species based on sediment characteristics/invertebrate community data etc., then the species can be excluded from further assessment.

9.16 For the remaining species, the importance of the intertidal oyster cultivation area(s) should be calculated as follows.

- In sites where the assessment is being carried out on proposed intertidal oyster cultivation, the percentage of the site population using the intertidal oyster cultivation area(s) should be calculated. This is preferably done by targeted counts, where birds within the intertidal oyster cultivation area(s) are counted separately. However, it is likely that assessments may be carried out using existing datasets that were collected for other purposes and did not clearly differentiate birds within the intertidal oyster cultivation area(s). In these cases, the percentage of the site population using the intertidal oyster cultivation area(s) can be calculated by taking a *pro-rata* fraction of the count from the count sector(s) containing the intertidal oyster cultivation area(s). However, expert judgment will be required in these situations to determine whether there are any factors (such as habitat variation or species behaviour) that might cause this method to produce a biased estimate of the percentage of the site population using the intertidal oyster cultivation area(s).

- In sites where the assessment is being carried out on existing intertidal oyster cultivation, the percentage of the site population using several defined areas of control habitat should be calculated. These control habitats should be defined so that they contain similar habitat to that which would have been present in the intertidal oyster cultivation area before cultivation started, and have similar availability to birds in terms of tidal exposure, bird movement patterns, etc. Several control areas should be used to control for factors that we cannot measure such as differences in prey availability, patchy prey distributions, etc. The predicted percentage of the site population that would occur in the intertidal oyster cultivation area in the absence of cultivation can then be derived from a *pro-rata* calculation.

9.17 For species with an **Exclusion** response, a significant negative impact is predicted where the intertidal oyster cultivation area supports, or is predicted to support in the absence of cultivation, 5% or more of the site population. The confidence levels for predictions for these species are high.

9.18 For species with a **Negative** response, species-specific criteria should be used as detailed below:-

Dunlin

- Intertidal oyster cultivation is predicted to reduce the occupancy of the affected area by a factor of 8. Therefore, the percentage displacement (D) can be calculated, using the number occurring within the intertidal oyster cultivation area (N) and the site population (P), as: -

$$D = (N-N/8)/P*100$$

- If D ≥ 5% then a significant negative impact is predicted.

- The reduction factor is conservative, so if D < 5% the confidence level for predicting no significant impact is high. If D > 5%, the confidence levels for predicting significant impacts are moderate for large flocks (>~ 50 birds) and low for small flocks (<~ 50 birds).

Bar-tailed Godwit

- If large (>~ 100 birds) flocks occur, or are likely to occur within the intertidal oyster cultivation areas then intertidal oyster cultivation is predicted to reduce the occupancy of the affected area by a factor of 7. Therefore, the percentage displacement (D) can be calculated as: -

$$D = (N-N/7)/P*100$$

- If small (<~ 100 birds) flocks occur, or are likely to occur within the intertidal oyster cultivation areas then intertidal oyster cultivation is predicted to reduce the occupancy of the affected area by a factor of 2. Therefore, the percentage displacement can be calculated as: -

$$D = (N-N/2)/P*100$$

- If D ≥ 5% then a significant negative impact is predicted.

- The confidence level for predictions for this species is high.

Shelduck, Ringed Plover, Lapwing, Sanderling, Black-tailed Godwit and Great Black-backed Gull

- These species appear to be negatively affected by oyster trestles, but there was insufficient data to calculate reductions in densities. Therefore, impact prediction has to make the conservative assumption that all birds are excluded from the affected area.

- A significant negative impact is predicted where the intertidal oyster cultivation area supports, or is predicted to support in the absence of cultivation, 5% or more of the site population.

- The confidence levels for predictions for these species are low.

9.19 For species with a **Variable** response, further site-specific assessment will have to be carried out.

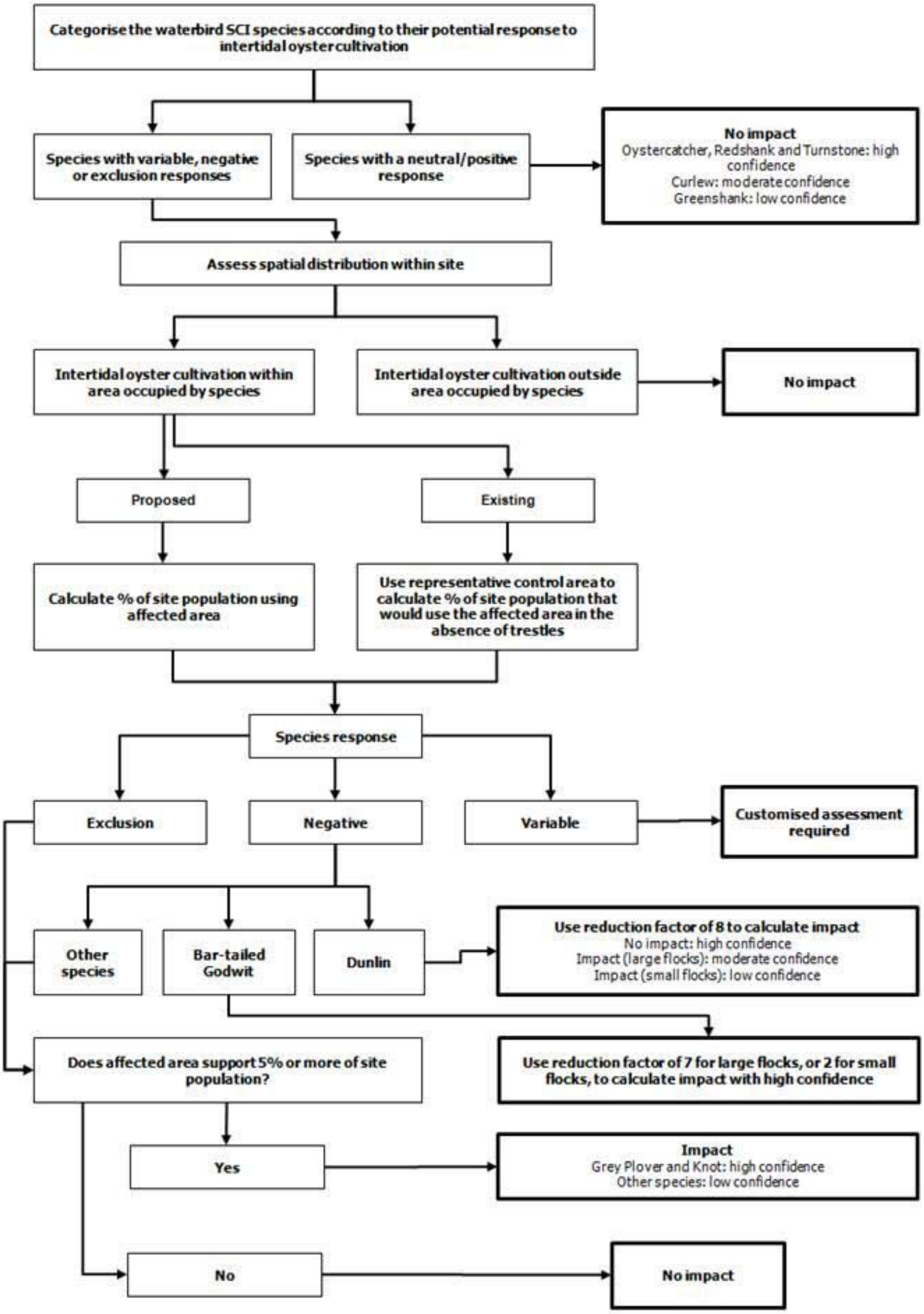


Figure 9.1 – Flowchart showing procedure for assessing the impact of intertidal oyster cultivation.

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Appendix A – Species codes and scientific names of bird species mentioned in the text

A.1.1 The following table lists the BTO species codes and the scientific names of the bird species mentioned in the text. The nomenclature follows Cramp and Simmons (2004), and American Ornithologists' Union (1998; for Black Turnstone, Long-billed Curlew and Marbled Godwit).

Code	Name	Scientific name
BA	Bar-tailed Godwit	*Limosa lapponica*
	Black Turnstone	*Arenaria melanocephala*
NT	Night Heron	*Nycticorax nycticorax*
BH	Black-headed Gull	*Larus ridibundus*
BW	Black-tailed Godwit	*Limosa limosa*
CF	Chough	*Pyrrhocorax pyrrhocorax*
CM	Common Gull	*Larus canus*
CX	Common Scoter	*Melanitta nigra*
CA	Cormorant	*Phalacrocorax carbo*
CU	Curlew	*Numenius arquata*
DN	Dunlin	*Calidris alpina*
GA	Gadwall	*Anas strepera*
GP	Golden Plover	*Pluvialis apricaria*
GD	Goosander	*Mergus merganser*
GB	Great Black-backed Gull	*Larus marinus*
	Great Blue Heron	*Ardea herodias*
GG	Great Crested Grebe	*Podiceps cristatus*
HW	Great Egret	*Ardea alba*
ND	Great Northern Diver	*Gavia immer*
GK	Greenshank	*Tringa nebularia*
H	Grey Heron	*Ardea cinerea*
GV	Grey Plover	*Pluvialis squatarola*
HG	Herring Gull	*Larus argentatus*
HC	Hooded Crow	*Corvus cornix*
KN	Knot	*Calidris canutus*
L	Lapwing	*Vanellus vanellus*
EP	Least Sandpiper	*Calidris minutilla*
LB	Lesser Black-backed Gull	*Larus fuscus*
PB	Light-bellied Brent Goose	*Branta bernicla hrota*
ET	Little Egret	*Egretta garzetta*
	Long-billed Curlew	*Numenius americanus*
MA	Mallard	*Anas platyrhynchos*
	Marbled Godwit	*Limosa fedoa*
MU	Mediterranean Gull	*Larus melanocephalus*
ML	Merlin	*Falco columbarius*
MH	Moorhen	*Gallinula chloropus*
OC	Oystercatcher	*Haematopus ostralegus*
PT	Pintail	*Anas acuta*
RN	Raven	*Corvus corax*
RM	Red-breasted Merganser	*Mergus serrator*

Code	Name	Scientific name
RK	Redshank	*Tringa totanus*
RH	Red-throated Diver	*Gavia stellata*
RP	Ringed Plover	*Charadrius hiaticula*
RC	Rock Pipit	*Anthus petrosus*
RO	Rook	*Corvus frugilegus*
SS	Sanderling	*Calidris alba*
SP	Scaup	*Athya marila*
SA	Shag	*Phalacrocorax aristotelis*
SU	Shelduck	*Tadorna tadorna*
SV	Shoveler	*Anas clypeata*
SN	Snipe	*Gallinago gallinao*
	Snowy Egret	*Egretta thula*
T	Teal	*Anas crecca*
TT	Turnstone	*Arenaria interpres*
ER	Western Sandpiper	*Calidris mauri*
WM	Whimbrel	*Numenius phaeopus*
WS	Whooper Swan	*Cygnus cygnus*
WN	Wigeon	*Anas penelope*
BA	Willet	*Catoptrophorus semipalmatus*

Appendix B – Detailed definition of count sectors

B.1 Ballymacoda Bay

B.1.1 CODA-OY was the area occupied by the oyster trestles.

B.1.2 CODA-CS1 was the area of intertidal sandflat between the oyster trestles and the southern shore of Ballymacoda Bay. A 50-200 m band of rocky shore habitat along the upper shore at Ring was not included in this count sector.

B.1.3 CODA-CS2 was the area of intertidal sandflat between the oyster trestles and the southern side of the Womanagh River channel.

B.1.4 CODA-CS3 and CODA-CS4 comprise the intertidal sandflat to the west of the oyster trestles. The division between CODA-CS3 and CODA-CS4 was a line extending from the southern boundary of the caravan park to the goal posts in the GAA pitch at Pilmore.

B.1.5 CODA-CN1 and CODA-CN2 generally corresponded to the NPWS low tide count sector OL573, but with the south-western boundary corrected to conform to the actual alignment of the Womanagh River. The division between the two sectors was a mussel bed (included in CODA-CN2) and a line, perpendicular to the shoreline, connecting the mussel bed to the shoreline. The division between these two sectors represented the point where the Womanagh River channel widens out from a clearly defined channel enclosed by steeply shelving sandbanks to an area with a tideline that retreats gradually across gently sloping intertidal habitat.

B.1.6 CODA-CN3 corresponded to the low tide count sector 0L 571. This sector contained extensive areas of mixed sediment substrate. The upper part of the mixed sediment substrate zone contained a high proportion of sandy substrate, while the lower part had much denser areas of hard sediments.

B.1.7 CODA-CN4 corresponded to the low tide count sector 0L 570. The southern part of this sector contained a dense area of mixed sediment substrate.

B.2 Bannow Bay

B.2.1 There were two count sectors containing oyster trestles: BANN-OY1 and BANN-OY2. Both these sectors were sub-divided to allow more fine-scale recording of waterbird distribution in relation to the presence of oyster trestles.

B.2.2 BANN-OY1 was located between two tidal channels and contained the main area of oyster trestles. The northern boundary of the sector was defined by a line running from a meander in the western tidal channel to the northernmost point of the oyster trestles. It was subdivided into three divisions containing oyster trestles and two divisions that were clear of trestles:

- BANN-OY1-O1 was on the western side of the sector and contained around 10 lines of oyster trestles running parallel to the shoreline.
- BANN-OY1-O2 and BANN-OY1-O3 contained irregularly arranged trestles scattered over a wide area with wide gaps between some trestles. The division between BANN-OY1-O2 and BANN-OY1-O3 was a line extending due south from VP2.
- BANN-OY1-C1 was a 50-75 m wide gap between BANN-OY1-O1 and the western edge of BANN-OY-O2. It also included the small area between the northern edge of BANN-OY1-O1 and the adjacent tidal channel.

- BANN-OY1-C2 was the main clear area in this sector extending to the north and west of the oyster trestles.

B.2.3 BANN-OY2 was located between two tidal channels and contained several groups of oyster trestles. The north-eastern and south-western boundaries of the sector were defined by lines running perpendicular to the eastern shoreline past the northernmost and southernmost limits of the oyster trestles. It was subdivided into four divisions containing oyster trestles and three divisions that were clear of trestles (Figure 3):

- BANN-OY2-O1 was a continuation of the dispersed area of oyster trestles in BANN-OY1-O3.
- BANN-OY2-O2, BANN-OY2-O3 and BANN-OY2-O4 were blocks of six-eight lines of trestles running parallel to the shoreline.
- BANN-OY2-C1 was a large, mainly clear area between BANN-OY2-O1 and BANN-OY2-O2. There were a few scattered trestles in this area.
- BANN-OY2-C2 was the clear area around and between BANN-OY2-O2, BANN-OY2-O3 and BANN-OY2-O4. It included a 20 m wide strip around the outer edges of the trestle blocks.
- BANN-OY2-C2 was the clear area between BANN-OY2-O4 and the tidal channel to the east.

B.2.4 The remaining count sectors were control areas lacking oyster trestles. Most of the boundaries corresponded to clear features, or have been described above. The remaining boundaries were as follows:

- The boundary between BANN-C1 and BANN-C2 was a shallow channel that remains partially flooded at low tide.
- The boundary between BANN-C4/BANN-C5 and BANN-C6 was a line bisecting the estuary running from the second headland to the east of VP2.
- The north-western boundary of BANN-C6 was drawn to exclude an area of mixed gravel/mud community shown on the biotope map of Bannow Bay.

B.3 Castlemaine Harbour

B.3.1 Difficulties were anticipated in counting all of the two outer count sectors (CAST-C1 and CAST-C4) due to the distances from the vantage points to the outer limits of these sectors. Therefore, the counter was instructed to define the outer boundaries of these count sectors in the field with reference to suitable landmarks.

B.3.2 The area along the southern shore was divided into small count sectors to reflect differences in substrate and patterns of oyster trestle usage and license applications. The boundaries between these sectors were defined as follows:

- The boundary between CAST-APP1 and CAST-C2 was a line from the point where the tidal channels to the west split to a distinct sharp bend on the western side of the tidal channel to the east.
- The boundary between CAST-OY1 and CAST-APP2/CAST-OY2 was the boundary between the mixed sediment substrate in CAST-OY1 and the sandy substrate in CAST-APP2/CAST-OY2. This change in sediment type was very distinct. The oyster trestles ran along the outer edge of CAST-OY1.

- The boundary between CAST-OY2 and CAST-APP2 was a line that forms a continuation of the boundary between CAST-OY1 and CAST-OY2 running west to the southern end of the tidal channel that formed the western boundary of CAST-OY2.
- The boundary between CAST-APP2 and CAST-OY3 was a line perpendicular to the shoreline that runs past the eastern edge of the saltmarsh islands to the southern end of the tidal channel.
- The boundary between CAST-OY3 and CAST-APP3 was a line that runs due north past the eastern edge of the saltmarsh islands.
- The boundary between CAST-OY3/CAST-APP3 and CAST-OY4 was a line that connected the southern ends of the two tidal channels.
- The boundary between CAST-APP3 and CAST-APP4 was a line that runs due south from the southern end of the tidal channel.
- The boundary between CAST-APP4 and CAST-C3 was a line that runs due north from the westernmost saltmarsh peninsula.
- The boundary between CAST-APP4/CAST-C3 and CAST-OY5 was a line that connects the southern end of the two tidal channels.

B.4 Dungarvan Harbour

B.4.1 There were four count sectors containing oyster trestles: DUNG-OY1, DUNG-OY2, DUNG-OY3 and DUNG-OY4. These count sectors extended approximately 3 km north along the lower shore east of the Cunnigar. The western limit of these sectors and the boundaries between the sectors were clearly delimited by the pattern of oyster trestle blocks. DUNG-OY1 and DUNG-OY2 contained large areas that were clear of trestles. DUNG-OY3 and DUNG-OY4 were almost entirely occupied by oyster trestles. In the field the eastern limit of these sectors was defined by the tideline.

B.4.2 There were four control sectors on the southern side of the bay. DUNG-CS1, DUNG-CS2 and DUNG-CS3 extended along the upper part of the shore between the Cunnigar and the oyster trestle sectors. DUNG-CS4 was the area of sandflat between the northern limit of the oyster trestles and the main tidal channel. The boundary between DUNG-CS1 and DUNG-CS2 was a line from the south-western corner of the main block of trestles to the car park at Ballynacourtey North. The boundary between DUNG-CS2 and DUNG-CS3 was a line from an isolated line of trestles (in a gap in the western edge of the main block of trestles) due west to the Cunnigar. The boundary between DUNG-CS3 and DUNG-CS4 was a line that is a continuation of the western edge of the main block of trestles. A small area of muddy sand biotope at the north-western corner of DUNG-CS3 was been excluded from this sector. The eastern limit of sector DUNG-CS4 will be defined by the tideline.

B.4.3 There were five control sectors on the northern side of the bay. DUNG-CN1 and DUNG-CN2 were on the eastern side of the tidal channel of the Glendine River. The boundary between DUNG-CN1 and DUNG-CN2 was a line extending west from a bend in the road. DUNG-CN3, DUNG-CN4 and DUNG-CN5 were on the western side of the tidal channel of the Glendine River. The boundary between DUNG-CN3 and DUNG-CN4 was a line extending due west from the tip of a small headland on the western shoreline. The southern boundary of DUNG-CN4 was the northern edge of an area of mixed sediment shore habitat that extends out into the bay. A continuation of this line formed the boundary between DUNG-CN4 and DUNG-CN5.

B.4.4 DUNG-CN1, DUNG-CN3 and DUNG-CN4 were sub-divided into lower shore (L) and upper shore (U) zones. The subdivision in DUNG-CN1 was a line extending due south from the small headland on the north-eastern shore of the sector. The subdivision in DUNG-CN3 and DUNG-CN4 was a line extending from the point where the railway line meets the beach on the northern shore of DUNG-CN3 to the easternmost limit of the rocky shore habitat.

B.5 Poulnasherry Bay

B.5.1 The count sectors were discrete areas of muddy sand substrate that were readily identifiable in the field.

B.6 Waterford Harbour

B.6.1 There were two count sectors containing oyster trestle blocks with some clear areas: FORD-OY1 and FORD-OY2. Their boundaries were defined by the configuration of the trestle blocks.

B.6.2 The remaining count sectors were control areas lacking oyster trestles.

B.6.3 The upper (western for FORD-C1, FORD-C3, FORD-C4, FORD-C5 and FORD-C6; eastern for FORD-C7) boundaries were the boundaries between the fine sand and muddy sand or mixed sediment habitat zones, which were clearly visible in the field.

B.6.4 The lower (eastern for FORD-C2, FORD-C3, FORD-C4, FORD-C5 and FORD-C6; western for FORD-C7) boundaries of all the count sectors was the tideline.

B.6.5 Divisions between adjacent sectors were defined as follows:

- The boundary between FORD-OY1 and FORD-C1 was the southern edge of the oyster trestle blocks.
- The boundary between FORD-OY2 and FORD-C4 was the northern edge of the oyster trestle blocks.
- The boundary between FORD-C4 and FORD-C5 was a line extending due east from a stream that flows down to the beach through a small gully below Carey’s Bridge.
- The boundary between FORD-C4 and FORD-C5 was a line extending due east from a track that runs down to the beach below the church at Crooke.

Appendix C – Count forms used in the extensive study

C.1 Bird count forms

C.1.1 Separate count forms were designed for the oyster trestle and control sectors.

C.1.2 Examples of the standard forms used for oyster trestle sectors with clear areas (Castlemaine Harbour), or without (Ballymacoda Bay), and control sectors (Bannow Bay) are shown.

C.1.3 Count forms for the oyster trestle sectors at BANN, and the control sectors at CODA and DUNG were customised to allow recording of site-specific details and these count forms are also shown.

C.2 Disturbance forms

C.2.1 A standard design for the disturbance form was used for all the sites. An example of the disturbance form for Ballymacoda Bay is shown on page

C.3 Disturbance maps

C.3.1 Maps for recording tideline positions and disturbance activities were prepared for each site. Two maps were prepared for each site to provide sufficient space for recording this information. For Ballymacoda Bay and Dungarvan Harbour, separate maps were prepared for the northern and southern sides of the bays. For Bannow Bay, Castlemaine Harbour, Poulnasherry Bay and Waterford Harbour, an overall map of the whole study area and a larger scale map of the area around the oyster trestles were prepared. An example disturbance map (for the northern sectors at CODA) is shown.

Oyster cultivation study: Castlemaine Harbour

Count form for oyster trestle sectors

Sector:	
Counter:	
Date:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover	1: 0-33%	2: 33-66%	3: 66-100%
Rain	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction			
Visibility	1 good	2 moderate	3 poor

	Within oyster trestle areas						Outside oyster trestle areas			
	On trestles		Tideline		Intertidal		Tideline		Intertidal	
Species	F	R	F	R	F	R	F	R	F	R
Notes:										

Oyster cultivation study: Ballymacoda Bay
Count form for oyster trestles

Counter:	
Date:	
Sector:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover:	1 0-33%	2 33-66%	3 66-100%
Rain:	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction:			
Visibility	1 good	2 moderate	3 poor

Species	On trestles		Intertidal		Tideline	
	F	R	F	R	F	R

Notes:

Oyster cultivation study: Bannow Bay
Count form for control sectors

Counter:	
Date:	
Sector:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover:	1 0-33%	2 33-66%	3 66-100%
Rain:	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction:			
Visibility	1 good	2 moderate	3 poor

Species	Intertidal		Tideline	
	F	R	F	R

Notes:

Oyster cultivation study: Bannow Bay

Count form for sector BANN-OY1

Counter:	
Date:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover	1: 0-33%	2: 33-66%	3: 66-100%
Rain	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction			
Visibility	1 good	2 moderate	3 poor

	BANN-OY1-O1			BANN-OY1-O2			BANN-OY1-O3			BANN-OY1-C1		BANN-OY1-C2	
Species	On trestles	Tideline	Intertidal	On trestles	Tideline	Intertidal	On trestles	Tideline	Intertidal	Tideline	Intertidal	Tideline	Intertidal
Notes:													

Oyster cultivation study: Bannow Bay

Count form for sector BANN-OY2

Counter:	
Date:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover	1: 0-33%	2: 33-66%	3: 66-100%
Rain	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction			
Visibility	1 good	2 moderate	3 poor

	BANN-OY2-O1			BANN-OY2-O2		BANN-OY2-O3		BANN-OY2-O4		BANN-OY2-C1		BANN-OY2-C2	BANN-OY2-C3	
Species	On trestles	Tideline	Intertidal	On trestles	Intertidal	On trestles	Intertidal	On trestles	Intertidal	Tideline	Intertidal		Tideline	Intertidal
Notes:														

ATKINS

Oyster cultivation study: Ballymacoda Bay

Count form for control sectors

Counter:	
Date:	
Sector:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover:	1 0-33%	2 33-66%	3 66-100%
Rain:	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction:			
Visibility	1 good	2 moderate	3 poor

Species	Clear sand				Mixed sediment			
	Intertidal		Tideline		Intertidal		Tideline	
	F	R	F	R	F	R	F	R

Notes:

Oyster cultivation study: Dungarvan

Count form for control sectors

Counter:	
Date:	
Sector:	
Time:	
Count affected by disturbance?	

Weather (circle as appropriate)			
Cloud cover:	1 0-33%	2 33-66%	3 66-100%
Rain:	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction:			
Visibility	1 good	2 moderate	3 poor

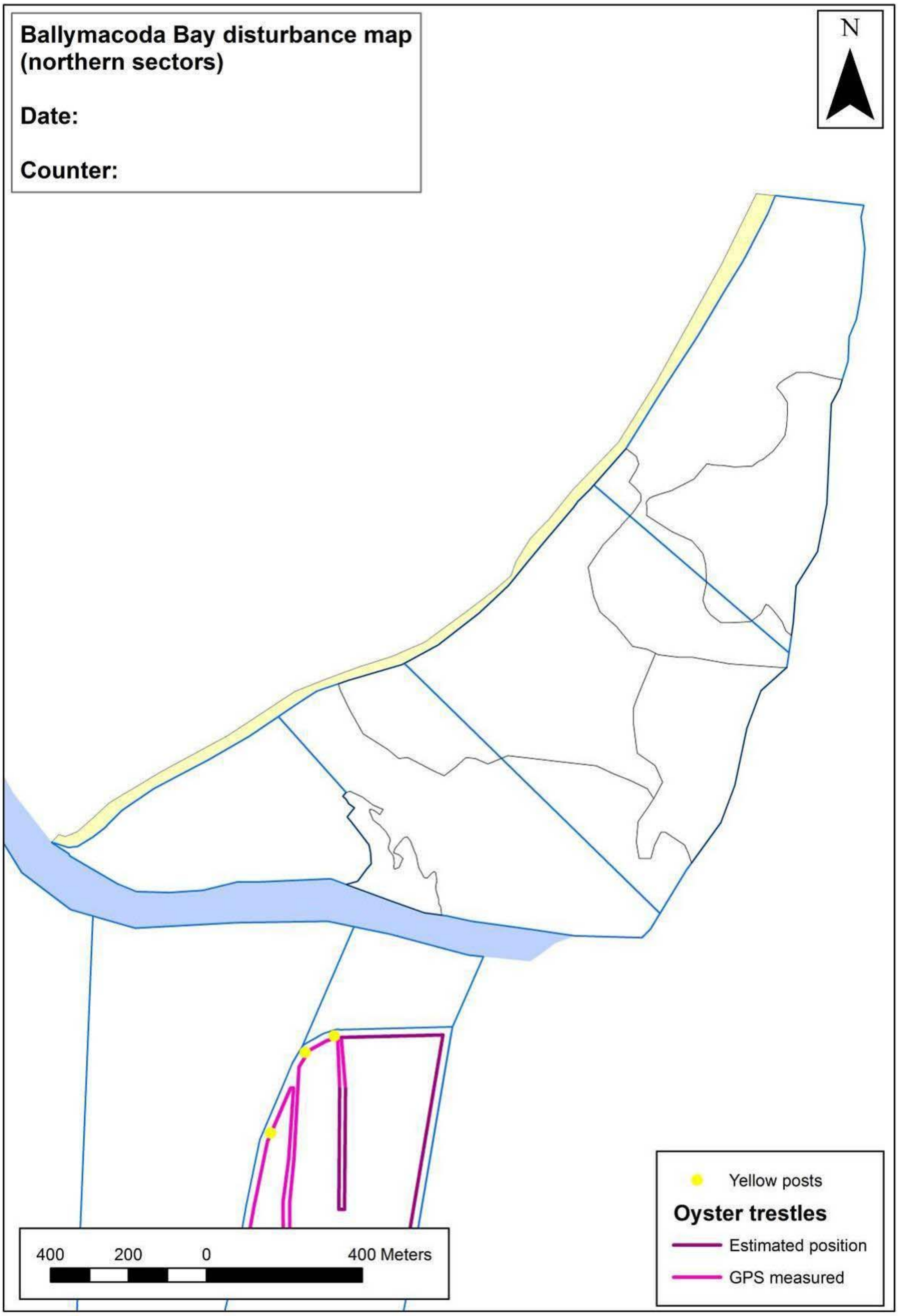
Species	Tidal channel		Intertidal (L)		Intertidal (U)	
	F	R	F	R	F	R

Notes:

Ballymacoda Bay oyster culture study: Disturbance form

Counter:	
Date:	

Event	Start time	End time	Number of vehicles	Number of people	Impact	Description of activity and impacts (if any)


Ballymacoda Bay disturbance map (northern sectors)
Date:
Counter:
N
Yellow posts
Oyster trestles
Estimated position
GPS measured
400
200
0
400 Meters

Appendix D – Count forms used in the intensive study

D.1.1 The count forms used in the intensive study were approximately A6 size and were pasted into a “policeman’s” style notebook (i.e., a notebook which opens by flipping over the top).

D.1.2 The waterbird count data for each sector was entered on a two page spread (see next page).

D.1.3 Data on flooding and tractor numbers was entered onto a single form for each count series.

D.1.4 Tideline positions and the spatial extent of disturbance events were sketched on a disturbance map, with more than one map being used, if necessary for clarity. Notes on each disturbance event were recorded on blank notebook pages.

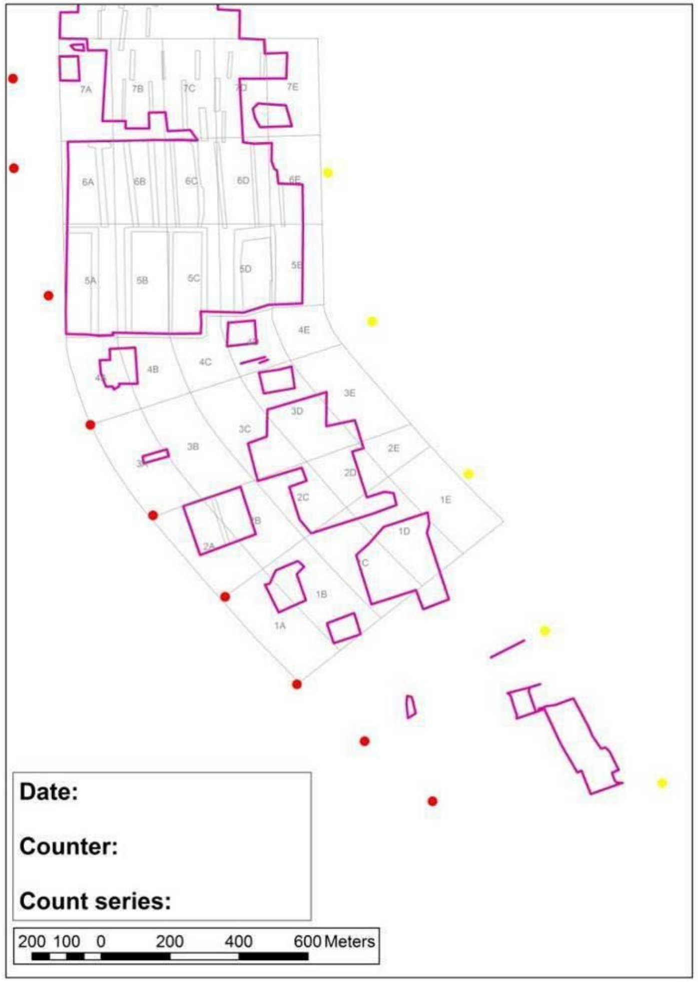
D.1.5 Blank copies of the forms used are shown on the following pages.

Date, time, sector:					
Sp	Loc	Band		Feeding	Roosting
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		

			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		
			TL I		

Sector	%flooded	Band A	Band B	Band C	Band D	Band E
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					
	shallow					
	deep					

Time						
OY1						
1						
2						
3						
4						
5						
6						
7						
OY4						
Arriving						
Leaving						
Time						
OY1						
1						
2						
3						
4						
5						
6						
7						
OY4						
Arriving						
Leaving						


7A
7B
7C
7D
7E
6A
6B
6C
6D
6E
5A
5B
5C
5D
5E
4B
4C
4E
3B
3C
3D
3E
2A
2C
2D
2E
1A
1B
1D
1E
Date:
Counter:
Count series:
200 100 0 200 400 600 Meters

Appendix E – Strategic study: Bird count totals

E.1.1 Total numbers recorded in the main counts at all the study sites are shown in Table E.1-E.6.

E.1.2 Numbers recorded in the partial additional counts at Ballymacoda Bay, Dungarvan Harbour and Poulnasherry Bay are compared to numbers recorded from the same sectors in the main counts on the same count days in Tables E.7-E.9.

Table E.1 - Total counts at Ballymacoda Bay.

Date	04/01/2011		20/01/2011		08/02/2011		21/02/2011	
Count	1	2	1	2	1	2	1	2
Light-bellied Brent Goose	74	149	21	78	91	78	83	53
Wigeon	625	877	350	428	126	9	78	60
Cormorant	19	14	5	7	4		8	9
Grey Heron	12	4	14	10	1	1	1	1
Oystercatcher	138	118	164	164	116	84	158	154
Ringed Plover	23	14		9	4	6	2	4
Golden Plover	38	22	1		380	77	530	153
Grey Plover	67	73	60	158	251	133	157	194
Lapwing	27			1	171	238		
Knot	158	226	102	86	104	83	50	4
Sanderling	59	83	48	110	50	63	5	20
Dunlin	808	614	1088	578	668	352	1134	931
Bar-tailed Godwit	364	649	445	650	921	366	554	635
Curlew	23	11	165	119	41	27	61	71
Greenshank	7	1	8	2	3	2	3	5
Redshank	53	44	90	78	30	31	78	59
Turnstone	33	38	3	4	10	4	10	8
Black-headed Gull	60	17	140	29	6	30	27	25
Common Gull	13	13	82	69	112	206	190	108
Lesser Black-backed Gull			69	56	55	49	9	
Herring Gull	101	45	25	61	98	70	87	81
Great Black-backed Gull	13		12	66	22	20	26	16
Hooded Crow	32	41	50	21	40	16	18	28

Additional species recorded (mean count less than 5) Teal, Red-breasted Merganser, Great Northern Diver, Great Crested Grebe, Shag and Little Egret.

Table E.2 - Total counts at Bannow Bay

Species	04/01/2011	23/01/2011	03/02/2011	17/02/2011
Light-bellied Brent Goose		535		376
Shelduck	58	230	241	72
Wigeon	17	36		44
Mallard	19	113		
Red-breasted Merganser	2	5		11
Oystercatcher	159	52	100	128
Golden Plover				682
Grey Plover	12	30	7	7
Lapwing	18	107	265	902
Dunlin	968	758	542	971
Black-tailed Godwit	152		125	28
Bar-tailed Godwit	428	539	430	927
Curlew	101	229	155	303
Greenshank	3	11	5	13
Redshank	117	147	125	164
Turnstone		4	9	13
Black-headed Gull	11	812	211	289
Common Gull		16	15	15
Lesser Black-backed Gull	5	4	8	42
Herring Gull	22	2	9	30
Hooded Crow	7	8	13	9

Additional species (mean count < 5): Goosander, Great Crested Grebe, Cormorant, Shag, Little Egret, Grey Heron and Ringed Plover.

Table E.3- Total counts at Castlemaine Harbour.

Species	05/01/2011	24/01/2011	03/02/2011	23/02/2011
Light-bellied Brent Goose	16	41	40	146
Shelduck	117	74	65	48
Wigeon	69	106	143	47
Teal	41	33	18	12
Mallard	128	109	123	61
Shoveler	7	5	64	
Cormorant	9	19	11	36
Grey Heron	21	12	3	3
Oystercatcher	313	210	134	93
Grey Plover	23	12	10	2
Lapwing		5	176	12
Knot	369	589	474	
Sanderling	15	15	30	32
Dunlin	86	140	357	57
Black-tailed Godwit	103	83	70	2
Curlew	222	259	270	94
Greenshank	15	21	10	11
Redshank	273	168	79	99
Turnstone	38	20	13	50
Black-headed Gull	629	540	240	340
Common Gull	78	33	84	79
Herring Gull	99	107	86	33
Great Black-backed Gull	32	51	52	44
Hooded Crow	84	82	43	60

Additional species (mean count < 5): Red-breasted Merganser, Little Egret, Ringed Plover, Snipe, Bar-tailed Godwit, Lesser Black-backed Gull and Raven.

Note: These totals differ from those presented (from the same series of counts) in Table 3.3 of Gittings and O'Donoghue (2011), as the latter exclude sectors C1 and C4.

Table E.4 - Total counts at Dungarvan Harbour.

Species	06/01/2011	22/01/2011	03/02/2011	21/02/2011	03/03/2011
Light-bellied Brent Goose	225	146	83	203	353
Red-breasted Merganser	3	8		4	12
Oystercatcher	152	189	178	219	115
Ringed Plover			1	54	48
Golden Plover		211	200	460	109
Grey Plover	20	11	20	16	54
Knot	166			448	181
Dunlin	390	132	24	788	389
Black-tailed Godwit	136	4	3	15	
Bar-tailed Godwit	148	760	565	598	397
Curlew	7	135	87	240	84
Redshank	172	72	99	267	246
Turnstone	21	11	14	23	41
Black-headed Gull	124	451	132	471	106
Common Gull	18	280	100	327	97
Lesser Black-backed Gull	4	39	381	22	53
Herring Gull	34	26	153	94	61
Great Black-backed Gull	26	5	7	12	67
Hooded Crow	30	31	16	37	39

Additional species (mean count < 5): Mallard, Great Northern Diver, Cormorant, Little Egret, Grey Heron, Lapwing, Sanderling, Whimbrel, Greenshank, Mediterranean Gull, Rock Pipit, Rook.

Table E.5 - Total counts at Poulnasherry Bay.

Species	04/01/2011	21/01/2011	03/02/2011	20/02/2011
Shelduck	33	13	5	54
Teal	15	51		
Oystercatcher	7	8	2	1
Grey Plover	26	18	16	2
Dunlin	325	420	310	215
Curlew	31	81	23	27
Redshank	27	28	6	5
Black-headed Gull	3	6	10	69
Common Gull	21	2	10	30

Additional species (mean count < 5): Light-bellied Brent Goose, Wigeon, Little Egret, Black-tailed Godwit, Bar-tailed Godwit, Greenshank, Turnstone, Herring Gull, Great Black-backed Gull and Hooded Crow.

Table E.6 - Total counts at Waterford Harbour

Species	10/01/2011	19/01/2011	03/02/2011	17/02/2011
Light-bellied Brent Goose	109	260	3	83
Oystercatcher	111	122	177	143
Sanderling		36		7
Bar-tailed Godwit	14	82	21	43
Curlew	20	22	93	127
Redshank	16	13	7	15
Black-headed Gull	88	795	129	231
Common Gull	25	224	146	655
Lesser Black-backed Gull	77	68	4	10
Herring Gull	37	54	110	74
Great Black-backed Gull	21	79	22	28
Hooded Crow	3	5	15	12

Additional species (mean count < 5): Cormorant, Grey Heron, Ringed Plover, Lapwing, Dunlin, Greenshank and Turnstone.

Table E.7 – Additional partial third counts at Ballymacoda Bay, compared to numbers recorded from the same sectors in the main counts on the same count days

	Count day 2						Count day 2								
Sector	CS3			CS4			CS3			CS4			OY		
Count series	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Light-bellied Brent Goose									18				2	3	27
Wigeon			110	53					11	63	48	133			
Great Crested Grebe															
Cormorant							4	5						1	
Little Egret										1		1			
Grey Heron													1	1	
Oystercatcher	17	24	17	43	26	34	21	3	24	35	18	29	14	12	
Ringed Plover		6	6									4			
Golden Plover				1											
Grey Plover	13	1	43			42	37		82			13			
Lapwing					1										
Knot		6	46	7	4	36			31			19			
Sanderling			35						43						
Dunlin	16	85	715	25	14		325		645			12			
Bar-tailed Godwit	6	2	113	2	11	115	11		232	1		6			
Curlew	7	7	10	107	62	19	16	31	13	12	22	29			
Greenshank				1			1		2	1	2	3	1	1	
Redshank	6	21	6	33	22	24	9	23	22	25	10	39	11	16	

	Count day 2						Count day 2								
Sector	CS3			CS4			CS3			CS4			OY		
Count series	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Turnstone				2					1	5	6	2			
Black-headed Gull		18		1		6	2	21	16			1	1		
Common Gull		8	22			2	24	38	37	2		1			
Lesser Black-backed Gull	26			43	31	18	7		15	1					
Herring Gull			9		14	14			6	2	1	3	17	10	
Great Black-backed Gull	6	4	12	2	33	15	11		12	1					
Hooded Crow			1	1		1				1	2	6	1	1	

Table E.8 - Additional partial second count at Dungarvan Harbour on count day 1, compared to numbers recorded from the same sectors in the main count on the same count day.

Sector	CS2		CS3		CS4		OY3		OY4	
Count series	1	2	1	2	1	2	1	2	1	2
Light-bellied Brent Goose					8		6	37	5	28
Oystercatcher	4	9	5	7			50	37	28	34
Grey Plover		3	11	2						
Sanderling							1			
Dunlin		32	39	103			23		13	24
Bar-tailed Godwit		24		1			17	32	21	30
Curlew								1	1	1
Redshank	1	16		2			20	36	16	34
Turnstone							2	3	2	7
Black-headed Gull				2			5	1	29	12
Common Gull		6	1	7			1	27		16
Herring Gull			2				12		6	7
Hooded Crow	1		3				6		2	

Table E.9 - Additional partial second counts at Poulnasherry Bay, compared to numbers recorded from the same sectors in the main counts on the same count day.

	Count day 1				Count day 2				Count day 3				Count day 3			
Sector	C1		OY		C1		OY		C1		OY		C1		OY	
Count series	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Light-bellied Brent Goose						3										
Shelduck	5	7							5	5						
Wigeon		6														
Teal	1	55			51	8										
Mallard				1												
Little Egret			1	1			1					2			1	
Oystercatcher	2	1	5	5			6	1				2				4
Grey Plover				2			1	2				2				
Dunlin	25		77	10	271		4	29		1		2				
Black-tailed Godwit							2	13			1				1	4
Bar-tailed Godwit			4	3												
Curlew	7	3	4	10		5	14	4	2	26	4	9	1	1	7	10
Greenshank	1	1	2	2												1
Redshank	1		25	19			5	3			2	11	1		4	23
Turnstone			2													
Black-headed Gull			1	1			2				2	5			2	10
Common Gull	1		1	2			1					1				3
Great Black-backed Gull													1			
Hooded Crow			2	2			1					2			1	1

Appendix F – Intensive study: Bird count totals

Table F.1 – Total counts, excluding sector OY1.

	05 Jan		06 Jan	20 Jan		21 Jan	22 Jan	24 Jan	01 Feb		03 Feb	17 Feb	21 Feb	23 Feb	03 Mar	07 Mar	
Count	1	2	1	1	2	1	1	1	1	2	1	1	1	1	1	1	2
Light-bellied Brent Goose	117	86	114	26	13	16	22	48	47	24	16	11	39	62	84	94	51
Red-breasted Merganser	0	0	0	0	0	0	0	2	0	0	0	3	0	1	0	1	2
Great Northern Diver	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Cormorant	0	0	1	0	0	0	0	0	1	2	0	1	0	0	0	0	1
Grey Heron	3	2	5	3	1	1	4	0	2	0	0	0	1	0	0	1	0
Oystercatcher	70	83	80	76	64	94	76	98	82	65	87	77	53	86	48	49	70
Grey Plover	0	24	0	0	1	5	9	3	7	14	0	0	0	9	25	4	19
Knot	0	0	0	0	0	0	0	0	0	155	0	0	0	0	20	0	0
Sanderling	0	0	6	0	0	0	0	0	0	0	0	15	1	0	0	0	0
Dunlin	41	40	88	37	34	21	15	6	144	40	3	382	16	14	289	3	7
Bar-tailed Godwit	75	80	69	47	63	71	78	44	61	94	46	83	64	127	43	41	42
Whimbrel	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0
Curlew	7	3	0	29	19	29	37	32	18	3	25	1	20	12	3	1	5
Greenshank	0	1	2	0	0	0	1	3	1	1	2	0	2	0	0	1	2
Redshank	49	67	107	86	96	68	42	30	80	68	58	118	119	109	111	65	90
Turnstone	5	6	2	8	12	4	5	5	11	9	7	31	7	13	16	4	16
Black-headed Gull	18	25	50	326	45	468	303	31	34	52	43	152	308	105	28	13	21
Common Gull	2	2	10	357	45	131	80	26	15	2	18	57	44	68	3	55	32
Mediterranean Gull	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

	05 Jan		06 Jan	20 Jan		21 Jan	22 Jan	24 Jan	01 Feb		03 Feb	17 Feb	21 Feb	23 Feb	03 Mar	07 Mar	
Count	1	2	1	1	2	1	1	1	1	2	1	1	1	1	1	1	2
Lesser Black-backed Gull	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Herring Gull	16	22	12	2	3	23	21	19	6	9	40	13	30	22	12	26	16
Great Black-backed Gull	0	0	0	0	0	0	2	0	0	0	2	0	0	0	1	7	6
Hooded Crow	9	2	8	12	17	7	12	22	11	14	8	4	19	16	11	14	14
Rock Pipit	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0

Table F.2 - Total counts, including sector OY1.

	06 Jan	22 Jan	24 Jan	01 Feb		03 Feb	17 Feb	21 Feb	23 Feb	03 Mar	07 Mar
Count	1	1	1	1	2	1	1	1	1	1	1
Light-bellied Brent Goose	116	22	48	54	44	26	33	46	69	127	144
Red-breasted Merganser	0	0	2	0	0	0	3	0	1	5	1
Great Northern Diver	0	0	0	0	0	1	0	0	0	0	0
Great Crested Grebe	0	0	0	0	0	0	0	0	2	0	0
Cormorant	1	0	0	1	2	0	1	1	0	0	1
Grey Heron	5	4	1	4	0	0	0	1	0	0	1
Oystercatcher	88	76	193	95	71	92	85	70	100	71	73
Grey Plover	5	9	29	16	14	20	0	0	17	51	4
Knot	0	0	0	0	155	0	0	0	0	36	0
Sanderling	6	0	0	0	0	0	15	1	0	0	0
Dunlin	88	15	37	144	40	15	382	16	14	289	3

	06 Jan	22 Jan	24 Jan	01 Feb		03 Feb	17 Feb	21 Feb	23 Feb	03 Mar	07 Mar
Count	1	1	1	1	2	1	1	1	1	1	1
Bar-tailed Godwit	70	78	62	65	100	54	103	91	170	61	45
Whimbrel	0	0	0	0	0	1	0	0	0	2	0
Curlew	1	37	38	22	6	29	2	37	24	21	5
Greenshank	2	1	6	4	2	2	4	7	1	1	5
Redshank	134	42	50	84	85	74	137	140	118	156	79
Turnstone	2	5	6	11	9	8	31	7	13	16	4
Black-headed Gull	71	303	34	38	52	46	173	352	109	28	13
Common Gull	15	80	100	17	5	27	100	61	71	3	55
Mediterranean Gull	0	0	0	0	0	1	0	0	0	0	0
Lesser Black-backed Gull	2	0	0	0	18	131	1	0	4	0	0
Herring Gull	18	21	48	9	9	112	19	45	111	26	32
Great Black-backed Gull	23	2	17	3	10	4	6	5	19	9	9
Rock Pipit	0	0	1	0	0	1	0	0	0	1	1
Hooded Crow	10	12	39	11	15	8	4	19	16	11	19

Atkins is one of the world's leading providers of professional, technology based consultancy services. With over 15,600 staff worldwide, Atkins has expanded in recent years from its historical base in traditional engineering into related technological consultancy services. In Ireland, Atkins can deliver the full range of services to clients in both the public and private sector.

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